KENAI RIVER SOCKEYE SALMON SMOLT STUDIES, 1992

Bruce E. King

Linda K. Brannian

and

Kenneth E. Tarbox

Regional Information Report[1] No. 2A93-28

Alaska Department of Fish and Game
Commercial Fisheries Management and Development Division
333 Raspberry Road
Anchorage, Alaska 99581

January 1994

[1] Contribution 2A93-28 is from the Soldotna area office. The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series may undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Commercial Fisheries Management and Development Division.

AUTHORS

Bruce E. King is an Assistant Research Project Leader for the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Region II, Upper Cook Inlet, 34828 Kalifornsky Beach Road Suite B, Soldotna, AK 99669.

Linda K. Brannian is the Regional Biometrician for the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Region II, 333 Raspberry Road, Anchorage, Alaska, 99518

Kenneth E. Tarbox is the Research Project Leader for the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Region II, Upper Cook Inlet, 34828 Kalifornsky Beach Road Suite B, Soldotna, AK 99669.

ACKNOWLEDGEMENTS

We would like to acknowledge the permanent seasonal staff responsible for collecting the data: Dave Westerman (Crew Leader), Mark Schlenker, Bill Glick, Kerri Derning, Dennis Beliveau, Laura Pillifant, Jennifer Brannen and James Browning. Steve Fried and Brian Bue also contributed to the planning of the project and review of the results.

PROJECT SPONSORSHIP

This investigation was partially financed by Exxon Valdez Oil Spill Restoration funds under Fish/Shellfish Study Number 27 titled *"Sockeye Salmon Overescapement"*.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES, continued

LIST OF FIGURES

LIST OF FIGURES, continued

ABSTRACT

Four inclined plane traps were placed in the Kenai River to capture seaward migrating sockeye salmon smolt. Only 3,166 sockeye smolt were captured, continuing a trend of decreasing total annual catches since the first year of the study, 1989, when 161,000 smolt were captured. Historic trap efficiency data were used to calculate a 1992 seaward migration estimate of approximately 377,000 smolt. The minimum migration, including Moose River and Hidden Creek smolt which were not sampled by our traps, was 617,000 smolt. Approximately 41% of the population was age-1. smolt and the remaining 59% were age-2. smolt. Capture of inanimate floating objects (radishes) released at different times and locations occurred primarily in near shore traps and averaged nearly 10% of the total release. Based on the absence of larger smolt from Moose River and Hidden Creek, and the capture of a greater percentage of released inanimate objects than smolt, we concluded that active trap avoidance did occur at the site in 1992.

KEY WORDS: Sockeye salmon smolt, *Oncorhynchus nerka*, biological sampling, migratory timing, bismark brown dye, mark-recapture, population estimation

INTRODUCTION

The Kenai River (Figure 1) typically contributes more than 50% to annual Upper Cook Inlet (UCI) commercial harvests of sockeye salmon *Oncorhynchus nerka* (Ruesch and Fox 1993). Forecasting the return of this stock is important to the successful management of the fishery. Forecasting has historically been based on a combination of adult escapement, average age specific maturity schedules, and average numbers of returns per spawner representing the classic escapement-return approach. The 1993 forecast is the first to include estimates of adult sockeye salmon projected from the number and age composition of sockeye salmon smolt migrating out of the Kenai River.

The Kenai River smolt project has provided an estimate of the number and age composition of sockeye salmon smolt migrating out of the drainage since 1989 (King et al. 1990, 1991) This information has been used to evaluate sockeye salmon production in the Kenai River drainage when used in conjunction with estimates of sockeye salmon spawners (King et al. 1992), sockeye salmon juveniles rearing in Kenai and Skilak lakes (Tarbox et al. 1993a), and adult salmon passing weirs across Hidden Creek (Fandrei 1992) and Russian River (Marsh 1991) tributaries. Comparable production studies are being done in the Kasilof River drainage, the second largest producer of sockeye salmon in UCI (Kyle 1992).

Commercial fishing closures in UCI due to the 1989 Exxon Valdez oil spill resulted in an extremely large spawning escapement into the Kenai River. A suite of projects was designed to evaluate the effects of large spawning escapements on resulting progeny and lake rearing habitat. The Kenai River smolt project has been funded as a component of the Natural Resource Damage Assessment Project *"Sockeye Salmon Overescapement"* since 1990 (Schmidt and Tarbox 1991, 1992).

Objectives of the Kenai River smolt project were to:

1. estimate the number of sockeye salmon smolt migrating seaward during the peak migration period from 15 May through 30 June;
2. determine the age composition, mean weight, and mean length of sockeye salmon smolt; and
3. describe daily and seasonal migration timing of sockeye salmon smolt.

METHODS

Fishing Methods

Four stationary floating inclined plane traps were placed in the Kenai River approximately 31 km upriver from the mouth (Figure 2). Traps were anchored from the left (south) bank with steel cable, and held at 9, 15, 21, and 24 m from shore with tubular aluminum booms (Figure 3). The inshore trap was designated trap 1.

The Kenai River was 105 m wide with a maximum water depth of 2.5 m at the trap location during the May and June study period. The thalweg occurred 25-30 m from the left bank and both current velocity and water depth decreased as one moved towards the right (north) bank. Traps were placed on the left side of the river in the area of highest surface water velocities and greatest flow volume, since we thought most smolt would travel downriver through this area (Hoar 1954, Foerster 1968, Bue et al. 1988).

Traps were similar in design to those used to estimate smolt migrations from the Crescent and Kasilof Rivers of UCI (Kyle 1983). Each trap was 2.1 m long, 1.5 m wide, and tapered in height from 1.05 m at the mouth to 0.1 m at the outlet or downstream end. Trap frames were constructed of angle aluminum and the bottom covered with perforated aluminum plate with 13 mm holes. The sides and top were covered with vexar plastic netting with 13 mm square mesh. The outlet end emptied into a 1.5 x 1.1 x 0.6 m live box which contained one vertical baffle. The mouth and outlet ends of the trap could be adjusted vertically to control fishing depth and the amount of water which entered the live box. Traps were typically fished to approximately 1.0 m below the surface. All traps were fished continuously throughout the study. Traps were monitored continuously and emptied at least twice between 0001 h and 0500 h, and then only checked sporadically and generally emptied once more between 2200 to 2300 h.

Estimating Smolt Abundance

Estimating Trap Efficiency

Methods employed to estimate trap efficiency (King et al, 1991) were modified in 1992. Smolt were dyed and released each day until a total of 3000 were released. No new releases of dyed smolt were made during the next 48 hours to allow those released to pass the counting site. This allowed trap efficiency to be evaluated for each 3000 smolt release time strata. Sockeye salmon smolt were dyed in a solution of 5 g Bismark Brown dye in 190 l of water (approximately 1:36,000) for twenty minutes. Dyeing was done in the morning, using the previous night's catch. All dyed smolt were transported upstream 3.2 km, transferred to a live box in the river and held for 12 hours prior to release. After live smolt were released, the dead smolt were counted to determine percent mortality from handling and dyeing. The in-river live box was replaced in mid-season with a live tank mounted in the boat used to transport dyed smolt. The water in this tank was constantly replaced by fresh river water using a battery operated pump. Smolt were dyed, held in the live tank for 12 hours, and then released in the same location used at the start of the season. This procedure reduced the number of times each smolt had to be handled during the capture and dyeing process. All smolt captured in the traps were examined for evidence of dye.

The number of smolt dyed (M_i) each marking period was set at 2,800 to obtain an estimate of abundance (N_i) with a relative error of +/- 25% for trap efficiencies equal to or greater than 2%. Trap efficiency was defined as the number of recaptures (r_i) divided by the number of smolt dyed and released. Required M_i for a given trap efficiency varied only slightly with number of smolt caught ($\hat{C}_i$), but increased dramatically with decreasing trap efficiency. A 2% trap efficiency was twice that seen in previous years, but sample size requirements for lower efficiencies would require handling more smolt then we thought we could capture and process. We also assumed that dye marking events could be pooled since trap efficiencies of adjacent time strata had not been significantly different in 1989 and 1990 (χ^2-test with $\alpha = 0.05$ critical level). Even pooling two adjacent strata would result in a sample size of 5,600 smolt, which would provide estimates with the desired relative error for trap efficiencies as low as 1%.

Our estimator, like other mark-recapture estimates of population size, was biased at low sample size (Seber 1982). To keep the level of bias below 10% enough smolt had to be marked to ensure that at least 10 dyed smolt were recaptured within each time strata. Fewer recaptures would result in a positive bias which would increase rapidly as recaptures fell below 10 smolt (Figure 4).

Analyses assumed: (1) all dyed sockeye salmon smolt released upstream moved past the trap site within 48 hours so dyed fish from one time period would not be caught in another; (2) the probability of capture among traps was the same for marked and unmarked smolt; (3) the probability of capture for each individual smolt was independent of that of other smolt; and (4) trap efficiency of each individual trap was independent of trap location within a period.

In addition to the regularly scheduled releases of dyed smolt, multiple releases of inanimate objects were done to gauge: 1) the relative cross sectional area of the river sampled by the traps; 2) the influence of release location on trap efficiency; and 3) the travel time of passive objects. Radishes were chosen for these releases because they were biodegradable and easily seen. A total of 24,000 radishes were placed in the river on six different dates. Releases of 2000 radishes each were made adjacent to both banks and in the middle of the river every two weeks, alternating weekly with releases of 2000 radishes from the left bank only. Radishes were dyed so that point of release could be determined, and only radishes that floated were released.

Estimating Sockeye Salmon Smolt Abundance

Sockeye smolt abundance ($\hat{N}_i$) in previous years was estimated as using LaPlace's ratio estimate (Cochran 1978) adapted by Rawson (1984):

$$\hat{N}_i = \hat{C}_i \frac{M_i}{r_i}\left[1 + \frac{M_i - r_i}{M_i r_i}\right] \quad , \tag{1}$$

where:

$\hat{N}_i$ = number of undyed sockeye smolt migrating past traps in period i
$\hat{C}_i$ = number of sockeye smolt caught in traps in period i
M_i = number of sockeye smolt dyed and released upstream in period i
r_i = number of dyed fish recaptured in traps in period i.

The variance of $\hat{N}_i$ was estimated as:

$$V(\hat{N}_i) = \hat{C}_i(\hat{C}_i+r_i)M_i\frac{(M_i-r_i)}{r_i^3} \quad , \tag{2}$$

and the (1-α) confidence interval as:

$$\hat{N}_i \pm z_\alpha\sqrt{V(\hat{N})} \quad , \tag{3}$$

where z_α = the (1-α)/2 percentage point of the standard normal distribution.

Sockeye smolt abundance in 1992 was estimated with a resampling technique (Effron 1982) based on the number of smolt dyed and recovered in 1989, 1990, and 1991. Data from each year were pooled when trap efficiencies were not significantly (χ^2 test, p = 0.05) different between time periods. Data for the entire season were pooled for both 1989 and 1991, but were split into two strata for 1990. These four pairs of M_i and r_i values were randomly chosen with replacement to produce estimates of 1992 smolt abundance using equation 1. The mean of five hundred bootstrap replications was used to estimate smolt abundance in 1992 (N_{92}):

$$N_{92} = \frac{\sum_{b=1}^{500} N_b}{500} \quad . \tag{4}$$

Variance of N_{92} was then calculated as:

$$V(N_{92}) = \frac{\sum_{b=1}^{500} (N_b - N_{92})^2}{500-1} \quad . \tag{5}$$

A 95% confidence interval was approximated by ranking the 500 estimates in ascending order and then using the 13th largest estimate (2.5 percentile) as the lower bound, and the 488th largest estimate (97.6 percentile) as the upper bound.

Run Timing

Migration timing was based on the proportion of the total catch made each day. We assumed that all smolt migrating from the Kenai River system passed the trap site during the operational period. Therefore the mean date of the migration was the date when 50% of the total migration had passed the trap site.

Age, Weight, and Length Sampling

Sockeye salmon smolt captured in traps were sampled for age, weight, and length (AWL) information. Because of small catches, desired sample sizes were not obtained for the 5 day time strata we originally set for AWL sampling. However, nearly all smolt not dyed for the mark-recapture experiment to estimate trap efficiency were sampled for AWL information. Sample periods were redefined as the number of days needed to collect at least 300 smolt. This sample size provides a binomial (two age classes) simultaneous 90% confidence interval of +/- 0.05 when the proportion of the major age class in the population is at least 0.75. For AWL sampling, a scale smear from the preferred area (INPFC 1963) of each smolt was placed on a standard laboratory slide for age determination, and then each smolt was weighed to the nearest 0.1 g and measured (fork length) to the nearest mm.

AWL data were also collected from sockeye smolt migrating from the Moose and Russian Rivers and Hidden Creek in 1992. Age composition, mean length and length frequencies for these samples were compared to values from samples collected at the mainstem site to determine whether these stocks were being captured by our Kenai River traps.

Climatological and Hydrological Sampling

Water velocity (m/sec) measurements were taken at the surface in front of each trap at 0.3 m incremental changes in river depth. Water depth (m), temperature (°C), and turbidity (maximum depth in m a secchi disc was visible) were measured daily.

RESULTS

Traps were fished from 16 May until 30 June 1992. Although we were prepared to subsample catches (King et al. 1991), the seaward migration was small enough to allow us to identify and count all fish captured.

A total of 15,399 fish were captured in the four traps (Tables 1 through 5). Traps 3 and 4 accounted for most (64%) of the captures, although catches from traps 1 and 2 were proportionally greater than noted for previous years (Table 6). Approximately 21% of the total catch was sockeye salmon smolt (3,166 smolt) . With the exception of sockeye and chinook *O. tshawytscha* smolt, captures of smolt and fry of other salmonid species exceeded those recorded in 1991 (King et al. 1991). In general, the numbers of smolt increased and the numbers of fry decreased with distance from shore. Sockeye smolt captures have decreased each year since the inception of the project in 1989 (Table 7).

Approximately one-half (1599 of 3166) of all sockeye salmon smolt captured were dyed and released upstream. Mean survival during the 12 hour holding period between dyeing and release was 0.579 for the 4 dye events, and ranged from 0.484 on 15 June, to 0.794 on 18 June (Table 8). Highest survivals occurred on the first and last dye events. The last dye event occurred after equipment and procedures were changed to reduce handlings of smolt. A total of 926 sockeye salmon smolt survived the dyeing process and were released. Of these, 19 were recaptured but less than 10 were recovered in any dye event. Recapture rates (trap efficiency) ranged from 0.013 to 0.035 with a mean value of 0.021. Dye events with the lowest trap efficiencies also had the lowest survival of dyed smolt prior to release.

Trap efficiencies for the years 1989 through 1991 varied from 0.007 to 0.013 (Table 9). The four pairs of M_i and r_i values used to generate the 500 bootstrap estimates for 1992 produced a mean estimate of 377,000 sockeye salmon smolt. The variance of the estimate was 7,663,000,000, and the 95% confidence bounds ranged from 246,000 to 469,000 sockeye smolt (Table 10).

Ninety-five percent of the total sockeye salmon seaward migration occurred between 4 and 20 June (Table 11). The peak day of migration, 15 June, accounted for 35% of the total sockeye smolt catch (Figure 5). Only 0.1% of the migration occurred during the first 19 days of counting. Age-2 sockeye smolt left the drainage slightly earlier than age-1 smolt.

An estimated 82.7% of the sockeye salmon smolt sampled at the km 31 site were age 2. (Table 12). There was a significant ($\chi^2=106.2$, $p=0.05$, 2 df) increase in the proportion of age-1. smolt in the sample from period 3. This shift in age composition has occurred each year of the project, and has also been observed in other sockeye smolt populations (Kyle et al. 1990, Bue et al. 1988, Kyle 1992).

Mean lengths and weights of sockeye smolt were greater in 1992 than in any of the previous three years (Table 13; Figures 6 and 7). The mean length of age-2. sockeye salmon smolt collected from the Russian and Moose Rivers was larger ($t=16.7$, $p<.001$, $t=36.7$, $p<.001$) than smolt sampled in the mainstem Kenai River (Table 14 and Figure 8). Hidden Creek sockeye salmon smolt were larger than either Russian or Moose River smolt (Fandrei 1992).

Seasonal trends in hydrological parameters were similar to previous years. Water level increased daily until mid-June, while temperature fluctuated between 9 and 14° C throughout the study at the km 31 site (Table 15). Changes in water clarity were not significantly correlated ($r = 0.574$, $p = 0.01$, 42 df) with changes in discharge (Figures 9 and 10).

Nearly 10% of the 24,000 radishes released in the river were recovered in the smolt traps (Table 16). A smaller proportion of radishes released adjacent to the right bank were recovered in the traps than those released in the middle of the river or near the left bank (Figure 11). Captures from middle river releases equaled or exceeded those of left bank releases. Visual observations indicated that up to one-fourth of the radishes released adjacent to the left bank were entrained in eddies above the traps over 24 hours later. Capture from mid- and left bank releases did not seem to be related to steady increases in water discharge and velocity (Figure 12). Regardless of release location, most radishes were caught in traps 1 and 2.

DISCUSSION

After the completion of the high water period resulting from local snow pack melt, there appeared to be a relationship between water level and turbidity. Increased flow associated with glacial melt and rain events tended to be followed by decreased clarity, with the reverse occurring during periods of stable or decreasing water levels.

Since few sockeye salmon smolt were caught, the 3,000 smolt sample size needed for a single dye event was not achieved in 1992. The number of smolt released, 926, would only provide a population estimate with a relative precision of +/- 25% if trap efficiency was 6%. In previous years, consistency in trap efficiency across dyeing strata allowed us to pool recapture data and thereby achieve the needed sample size for our desired level of precision. The small sample size in 1992 precluded any examination of changes in trap efficiency over time. In addition, the small number of dyed smolt recaptured (19) could have biased the mark-recapture estimate (Seber 1982). Consequently, estimates of seaward migration based on the 1992 trap efficiency data were thought to be unreliable. Our total 1992 estimate of 377,000 sockeye smolt, which was based on historic trap efficiency estimates, may be greater than the true value, and the 95% confidence interval (246,000-469,000 smolt) may be too narrow for a relative precision of +/- 25%. In spite of these problems, we feel that the decrease in total smolt catch relative to 1989 supports our conclusion that the 1992 seaward migration was very low. The 3,166 sockeye smolt captured in 1992 represented a continued dramatic decline in total sockeye smolt captured each year since 161,111 sockeye smolt were caught when the project began in 1989 (Table 7).

Releases of inanimate objects (radishes) were designed to evaluate smolt trap efficiency in the capture of passively drifting objects and to estimate the effective surface area of the river sampled if objects were randomly distributed across the river. We also hoped the experiment might help answer questions concerning smolt avoidance behavior. The 10% overall capture rate of radishes was almost ten times greater than the capture rate for dyed smolt. The radish capture rate also exceeded the expected 6% level of recapture based on total area of the river sampled by traps. Finally, while radishes were captured at higher rates in traps closest to shore, sockeye smolt have historically been captured in increasing numbers in traps furthest from shore. These data suggested that dyed smolt were not simply passively migrating downstream, but were actively seeking areas of the river which we did not sample, or avoided the traps. We were surprised that few radishes released near the right bank were captured, but are not sure how to interpret these results in relation to trap efficiency for smolt. In 1989 dyed smolt were released adjacent to both banks and in mid river on different dates (King et al 1990). Since trap efficiency did not change by period, we assumed that release location was not a factor affecting the probability of subsequent recapture. Consequently, we chose a single release location in a quiet water area in which smolt could be held prior to release. To examine the effect of release location on recapture, we would have to differentially mark smolt according to release location.

We were also concerned that larger smolt may have a different probability of capture in our traps than smaller smolt. Prior to 1992, age-2. sockeye smolt lengths from traps samples appeared to be normally distributed (Figure 13) which suggested that size selectivity was not occurring. We assumed that length frequency distributions would be truncated at larger values or be skewed toward smaller sizes if larger smolt were better able to evade capture. Length frequency data for Russian River, Moose River, and Hidden Creek sockeye smolt, first collected in 1992, suggested that Hidden Creek (age 1.) and Moose River sockeye smolt (age-2.) were not represented in mainstem trap catches since their length frequency distribution had little overlap with that measured for mainstem trap smolt samples (Figure 8). In contrast, there was sufficient overlap between the mainstem and Russian River age-2. length frequency distributions to infer that Russian River smolt were at least partially represented in mainstem catches. It appeared that under the water velocity regime measured and the trap placement scheme used in 1992, trap efficiency decreased as length approached approximately 120 mm.

A comparison of length frequency distributions for coho salmon captured in Moose River, Hidden Creek and the mainstem Kenai River also suggested size selectivity in trap catches (Figure 13). Carlon (1992) found a significant ($p < 0.001$) difference in mean length between coho tagged in the Moose River and those recovered in the traps, and felt that traps could not be used to estimate the number of coho salmon migrating seaward from that drainage.

In 1992, 99% of sockeye smolt collected from the Russian River were age 2. This agreed with past adult returns which have consisted predominantly of age-2.2 and -2.3 sockeye. In 1989, our data indicated that only 0.3% of the 23,876,000 smolt total estimate, 72,000 smolt, were age-2 smolt from the 1986 brood year (King et al 1990). Since the 1988 fall acoustic surveys of Kenai and Skilak lakes produced an estimate of 340,000 age-1.0 sockeye fry (Tarbox and King 1989), we assumed that our age-2 smolt estimate in 1989 was a reasonable estimate of winter survival (21%) of age-1 fry. We also assumed, based on length frequency data collected in the late 70's (Nelson 1980), that Russian River smolt were well represented in our samples. However, our age-2 smolt estimate was much too low, since the estimated total return of age 2.2 and 2.3 adult sockeye salmon to the Kenai River from the 1986 brood year was approximately 670,000, over nine times greater than the age-2 smolt estimate (D.Waltemyer, Commercial Fisheries Div., Soldotna, pers. comm.). In comparison, the 1986 brood year in the Kasilof River produced 3,000,000 age-2. smolt and the estimated adult return for this age class in 1991 and 1992 was approximately 350,000. This gave a reasonable smolt-to-adult survival rate of 12%.

There are four possible explanations for the large error in estimating age-2. smolt in 1989. We may have underestimated the age-2. component of the smolt migration by assuming an equal capture efficiency for age-1. and -2. smolt since we estimated trap efficiencies using only dyed age-1. smolt. We may have underestimated the total smolt migration since smolt-to-adult survival for the Kenai River, already over 25% without the age-2.3 component, has been much greater than that for the nearby Kasilof River over the last 9 years (mean = 15.1%, Kyle 1992). We may have inadequately sampled the smolt migration to accurately estimate the true percentage of age-2. smolt, although our sample sizes were set to estimate age composition within 5% the true proportion 90% of the time. We may have over-estimated the age-2.2 and -2.3 component of the adult return through the process used to allocate the catch, since we assumed an equal exploitation rate on all stocks and allocated the catch based on the proportion of each age class in escapements to the main spawning drainages. We currently do not have an independent method to allocate the catch to river of origin.

While age-2. Kenai River smolt production and survival for the 1986 brood year was obviously in error, estimates of age-2. smolt production and survival for subsequent years were reasonable. The 1990 smolt estimate included 5,758,000 age-2. smolt from the 1987 brood year. In 1992 an estimated 236,000 age-2.2 adults returned to the Kenai River. The return of age-2.3 adults, which will occur in 1993, is expected to be 489,000 based on a regression between age-2.2 and -2.3 returns ($r=0.61$, $p<0.05$). This would result in a total brood year return of 725,000 age-2. adults and a smolt-to-adult survival of 12.5%. Even if the 1993 age-2.3 return equaled the historical high of 816,000 (1990), survival of age-2. smolt would still be less than 20%.

The 1992 adult sockeye return provided the first opportunity to evaluate the accuracy of smolt estimates. The 1987 parent year escapement of 1,408,000 adult spawners (Table 18), produced approximately 37,000,000 age-0. fry which reared in the two major lakes in the drainage (Tarbox and King 1989). This was a minimum estimate of fry production since Russian River, Hidden Lake, and Moose River were not included. However, these systems are thought to produce only a small portion of average annual production. An estimated 23,804,000 age-1. smolt migrated to sea the following spring, 1989, giving a fry-to-smolt survival rate of 60-65%. The estimated total return to the Kenai River of age-1.2 adults in 1991 and -1.3 adults in 1992 was 7,500,000, giving an age-1. smolt to adult survival of approximately 32%. An additional 5,758,000 age-2. smolt from the 1987 brood year migrated from the drainage in 1990. The return of 211,000 age-2.2 adults in 1992 gave an age-2. smolt-to-adult survival rate of approximately 4%, but does not include age-2.3 sockeye adults which will return in 1993. The overall smolt-to-adult survival rate for the 1987 brood year was 26%, not including age-2.3 sockeye adults or any sockeye taken in interception fisheries. This survival rate, once age-2.3 adults returning in 1993 are included, will be outside the range of historic Tustumena Lake smolt-to-adult survivals of 9-25% for the 1979-1985 brood years (Kyle 1992).

The sockeye salmon smolt estimate for 1992 was considerably less than that expected from fall fry estimates adjusted for average winter survival. October 1991 lake surveys produced estimates of 7,127,800 age-0. and 386,500 age-1. fry in Kenai and Skilak Lakes (Tarbox et al. 1993a). If winter survival was average, 75%, approximately 5,000,000 age-1. and 300,000 age-2. smolt should have been produced from Kenai and Skilak Lakes, not including production form Hidden and Russian lakes or Moose River.

The final 1992 smolt estimate of 377,000 probably included some portion of the Russian River component, but none of the Hidden Lake and Moose River component. Since the latter two stocks contributed 192,000 and 48,000 smolt, respectively, minimum total seaward migration was approximately 617,000 sockeye salmon. When apportioned to age class, the minimum smolt estimate consisted of 41% age-1. and 59% age-2. smolt.

We do not know the reason for the less than expected 1992 smolt seaward migration estimate. The estimate may be accurate and reflect high mortality, perhaps due to rearing limitations. This was not the result of competition for food with fry remaining in the lake from previous brood years. Fall 1991 tow net studies indicated that age-1. fry comprised only 2.9% of the Kenai Lake and 5.4% of the Skilak Lake fry population estimates (Tarbox et al. 1993a). Since adult return data for the 1987 brood year produced a much greater than expected smolt-to-adult survival estimate, we also cannot discount the possibility that juvenile or smolt population estimates have much larger errors than we anticipated.

If estimates were reasonably accurate, our data suggest that sockeye salmon smolt production from the 1987-1989 parent years varied considerably despite record large escapements achieved in most of those years (Table 17). The 1987 parent year spawning escapement of 1,408,000 spawners produced 29,563,000 smolt. Most of these smolt (23,804,000) migrated to sea at age-1. Some juveniles, 5,758,000, remained in freshwater and migrated as age-2. smolt the next spring along with 5,069,000 age-1. smolt from the 1988 adult return. The 1988 adult spawning escapement of 910,000 also produced 418,000 age-2. smolt for a total smolt production of 5,487,000. The 1989 parent year adult spawning escapement of 1,379,000 produced 2,582,000 age-1. smolt and 312,000 age-2. smolt. The 1990 adult spawning escapement of 519,000 produced only 253,000 age-1. smolt. The age-2. component of the 1990 brood year will migrate to sea in 1993. However preliminary indications from 1992 fry surveys (Tarbox et al. 1993b) suggest that age-2. smolt production will not be great enough to raise smolt production to levels expected from the number of adults in the parent year escapement.

LITERATURE CITED

Bue, B.G., D.L. Bill, W.A. Bucher, S.M. Fried, H.J.Yuen, and R.E. Minard. 1988. Bristol Bay sockeye salmon studies for 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 88-15, Juneau.

Carlon, J. 1992. Feasibility of capturing and marking juvenile coho salmon for stock assessment in the Kenai River. Alaska Department of Fish and Game Division of Sport Fisheries Fishery Data Series No. 92-57.

Cochran, W.G. 1978. LaPlace's ratio estimator. *In* Contributions to survey sampling and applied statistics, *edited by* H.A. David, Academic Press, New York, pp. 3-10.

Effron, B. 1982. The jackknife, the bootstrap and other resampling plans. CBMS-NSF Regional Conference Series in Applied Mathematics 38, Society for Industrial and Applied Mathematics, Philadelphia.

Fandrei, G. 1992. Hidden Lake sockeye salmon enhancement progress report 1992. Cook Inlet Aquaculture Association, Soldotna

Foerster, R.E. 1968. The sockeye salmon, *Oncorhynchus nerka.* Fisheries Board of Canada Bulletin 162. Ottawa

Hoar, W.S. 1954. The behavior of juvenile pacific salmon, with particular reference to the sockeye (*Oncorhynchus nerka*). Journal of the Fisheries Research Board of Canada 11(1).

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Seattle, Washington.

King, B.E., R.Z. Davis, and K.E. Tarbox. 1992. Upper Cook Inlet salmon escapement studies, 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-2016, Juneau.

King, B.E., L.K. Brannian, and K.E. Tarbox. 1990. Kenai River sockeye salmon smolt studies, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2S90-5, Anchorage.

King, B.E., L.K. Brannian, and K.E. Tarbox. 1991. Kenai River sockeye salmon smolt studies, 1990-91. Alaska Department of Fish and Game Division of Commercial Fisheries Regional Information Report No. 2S91-8, Anchorage.

LITERATURE CITED, continued

Kyle, G.B. 1983. Crescent Lake sockeye salmon smolt enumeration and sampling, 1982. Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division Report Series No. 17, Juneau.

Kyle, G.B. 1992. Summary of sockeye salmon (*Oncorhynchus nerka)* investigations in Tustumena Lake, 1981-1991. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development Division Report No. 122, Juneau.

Kyle, G.B., D.S. Litchfield, and G.L. Todd. 1990. Enhancement of Hidden Lake sockeye salmon (*Oncorhynchus nerka*): Summary of fisheries Production (1976-1989). Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division Report No. 102, Juneau.

Marsh, L. 1991. Catch and effort statistics for the sockeye salmon sport fishery during the late run to the Russian River with estimates of escapement. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 92-22, Juneau.

Nelson, D.C. 1980. Russian River sockeye salmon study. Alaska Department of Fish and Game. Anadromous Fish Studies, Annual Performance Report, 1980 -1981, Project AFS-44, 22 (AFS-44-7):1-48, Juneau.

Rawson, K. 1984. An estimate of the size of a migratory population of juvenile salmon using an index of trap efficiency obtained by dye marking. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development Report 28, Juneau.

Ruesch, P.H. and J. Fox. 1993. Upper Cook Inlet Commercial Fisheries Annual Management Report, 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A93-17, Anchorage.

Schmidt, D. and K.E. Tarbox. 1991. Sockeye salmon overescapement. Fish/Shellfish Study No. 27. State/Federal Natural Resource Damage Assessment Draft Preliminary Status Report, Soldotna.

Schmidt, D. and K.E. Tarbox. 1992. Sockeye salmon overescapement. Fish/Shellfish Study No. 27. State/Federal Natural Resource Damage Assessment Draft Preliminary Status Report, Soldotna.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. second edition. Macmillan Publishing Co., New York.

Tarbox, K.E. and B.E. King. 1989. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques in 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2S89-07, Anchorage.

Tarbox, K.E., B.E. King and L.K. Brannian. 1993a. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques in 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report No. 93-01, Juneau.

Tarbox, K.E., B.E. King and L.K. Brannian. 1993b. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques in 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report (in progress), Juneau.

Table 1. Total numbers of fish captured by smolt traps at the Kenai River km 31 site, May 16 through June 30, 1992.

	Numbers of Fish								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
16–May	0	18	11	83	1	0	0	15	128
17–May	0	23	14	83	3	0	2	15	140
18–May	1	14	6	130	2	1	0	10	164
19–May	0	20	5	123	1	4	7	12	172
20–May	0	23	1	72	1	1	4	21	123
21–May	0	31	0	175	0	0	5	28	239
22–May	0	15	3	74	0	1	5	18	116
23–May	0	21	2	78	0	1	4	8	114
24–May	0	14	7	82	2	1	3	11	120
25–May	2	8	1	104	0	3	2	8	128
26–May	1	10	4	79	17	2	11	16	140
27–May	0	6	14	53	14	1	5	15	108
28–May	1	0	17	26	26	4	3	11	88
29–May	1	7	137	33	65	0	20	27	290
30–May	2	22	86	40	49	0	16	23	238
31–May	5	54	86	26	135	24	5	36	371
01–Jun	1	86	104	10	230	2	0	30	463
02–Jun	9	0	115	8	434	7	0	28	601
03–Jun	9	19	26	9	123	1	1	39	227
04–Jun	56	63	35	15	165	22	1	21	378
05–Jun	35	34	143	16	252	26	0	28	534
06–Jun	144	73	38	11	96	16	0	22	400
07–Jun	69	282	28	15	176	32	0	17	619
08–Jun	28	68	37	12	231	16	0	11	403
09–Jun	94	46	50	13	208	4	0	24	439
10–Jun	69	175	85	22	143	25	0	30	549
11–Jun	250	234	102	23	144	0	0	49	802
12–Jun	329	109	72	24	138	0	0	19	691
13–Jun	300	64	429	31	160	3	0	39	1,026
14–Jun	101	21	327	14	126	18	0	26	633
15–Jun	1,123	51	39	4	82	0	0	14	1,313
16–Jun	100	65	130	6	65	1	0	10	377
17–Jun	99	178	72	17	19	6	0	8	399
18–Jun	49	37	44	2	50	1	0	23	206
19–Jun	57	46	25	2	36	0	0	13	179
20–Jun	94	51	122	4	22	0	0	13	306
21–Jun	16	6	24	0	31	3	1	8	89
22–Jun	3	21	133	4	55	8	0	5	229
23–Jun	14	43	27	6	17	0	0	5	112
24–Jun	5	32	64	2	22	0	0	5	130
25–Jun	2	17	359	17	45	0	0	13	453
26–Jun	2	4	125	3	16	0	0	3	153
27–Jun	6	5	50	5	11	4	0	6	87
28–Jun	40	15	239	12	42	11	0	7	366
29–Jun	18	16	97	3	10	0	0	0	144
30–Jun	31	58	305	12	3	3	0	0	412
Total	3,166	2,205	3,840	1,583	3,468	252	95	790	15,399

Table 2. Numbers of fish captured by trap 1 in the Kenai River, May 16 through June 30, 1992.

	Numbers of Fish								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
16-May	0	18	2	53	1	0	0	2	76
17-May	0	23	2	57	1	0	0	2	85
18-May	0	13	0	41	1	0	0	1	56
19-May	0	16	0	68	0	3	2	2	91
20-May	0	21	0	56	1	0	2	0	80
21-May	0	21	0	53	0	0	0	1	75
22-May	0	13	1	46	0	0	2	3	65
23-May	0	20	0	64	0	1	0	1	86
24-May	0	12	0	56	0	1	2	3	74
25-May	0	7	0	81	0	3	0	0	91
26-May	0	9	0	74	0	1	7	1	92
27-May	0	5	8	49	1	0	1	3	67
28-May	0	0	10	20	13	1	1	3	48
29-May	1	6	32	31	6	0	3	5	84
30-May	0	10	20	29	1	0	0	9	69
31-May	1	51	16	21	3	18	3	9	122
01-Jun	1	85	25	10	13	1	0	12	147
02-Jun	0	0	20	7	16	1	0	12	56
03-Jun	0	14	4	9	3	1	0	14	45
04-Jun	0	57	4	7	13	11	0	7	99
05-Jun	1	33	20	15	7	9	0	8	93
06-Jun	1	56	3	6	4	7	0	7	84
07-Jun	3	265	2	9	6	20	0	5	310
08-Jun	0	68	10	3	7	11	0	0	99
09-Jun	1	34	13	0	2	0	0	4	54
10-Jun	3	149	8	17	2	17	0	5	201
11-Jun	2	159	13	8	4	0	0	8	194
12-Jun	5	63	8	10	6	0	0	1	93
13-Jun	4	31	30	12	9	0	0	13	99
14-Jun	5	11	45	6	4	7	0	12	90
15-Jun	6	28	3	0	6	0	0	2	45
16-Jun	1	27	9	0	3	1	0	2	43
17-Jun	0	75	9	8	0	0	0	1	93
18-Jun	1	23	3	0	4	0	0	3	34
19-Jun	1	32	1	1	0	0	0	2	37
20-Jun	6	24	7	1	0	0	0	3	41
21-Jun	2	0	2	0	1	2	0	2	9
22-Jun	0	11	5	3	1	0	0	3	23
23-Jun	1	26	1	2	1	0	0	5	36
24-Jun	0	20	8	1	0	0	0	2	31
25-Jun	0	8	77	4	1	0	0	3	93
26-Jun	0	2	14	2	0	0	0	1	19
27-Jun	0	3	10	2	0	0	0	1	16
28-Jun	1	6	21	0	0	1	0	0	29
29-Jun	0	13	12	2	0	0	0	0	27
30-Jun	0	26	22	0	0	0	0	0	48
Total	47	1,594	500	944	141	117	23	183	3,549

Table 3. Numbers of fish captured by trap 2 in the Kenai River, May 16 through June 30, 1992.

Date	Numbers of Fish: Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
16–May	0	0	3	4	0	0	0	1	8
17–May	0	0	2	11	1	0	0	4	18
18–May	0	0	1	37	1	1	0	3	43
19–May	0	2	3	41	1	0	2	2	51
20–May	0	0	0	4	0	1	1	9	15
21–May	0	3	0	51	0	0	0	6	60
22–May	0	2	0	21	0	1	1	4	29
23–May	0	1	1	3	0	0	2	2	9
24–May	0	0	4	11	0	0	0	3	18
25–May	0	0	0	16	0	0	2	0	18
26–May	0	0	0	3	4	0	0	2	9
27–May	0	1	3	2	1	1	2	3	13
28–May	1	0	5	2	6	1	1	2	18
29–May	0	0	39	1	10	0	4	10	64
30–May	0	3	24	3	3	0	7	3	43
31–May	0	2	15	1	27	1	0	5	51
01–Jun	0	0	17	0	27	1	0	7	52
02–Jun	1	0	13	1	52	1	0	1	69
03–Jun	1	0	8	0	13	0	1	4	27
04–Jun	8	2	6	5	15	9	0	5	50
05–Jun	2	1	33	1	24	4	0	5	70
06–Jun	5	7	2	2	9	6	0	7	38
07–Jun	9	17	5	6	14	7	0	5	63
08–Jun	0	0	5	0	22	1	0	5	33
09–Jun	4	12	8	10	14	0	0	7	55
10–Jun	3	7	17	2	12	2	0	1	44
11–Jun	10	51	18	0	14	0	0	9	102
12–Jun	20	25	7	9	10	0	0	3	74
13–Jun	24	13	62	4	7	0	0	10	120
14–Jun	3	1	61	4	12	3	0	9	93
15–Jun	44	9	4	0	5	0	0	2	64
16–Jun	6	27	13	0	5	0	0	2	53
17–Jun	8	47	8	3	0	0	0	1	67
18–Jun	3	6	2	1	5	1	0	4	22
19–Jun	3	7	6	1	3	0	0	4	24
20–Jun	16	12	14	0	1	0	0	0	43
21–Jun	3	5	2	0	1	1	0	1	13
22–Jun	0	2	14	0	3	2	0	0	21
23–Jun	0	6	2	1	1	0	0	0	10
24–Jun	1	3	9	1	3	0	0	0	17
25–Jun	0	1	39	3	3	0	0	2	48
26–Jun	0	2	20	0	4	0	0	1	27
27–Jun	0	1	9	3	1	0	0	3	17
28–Jun	9	6	29	1	3	0	0	2	50
29–Jun	3	1	20	1	0	0	0	0	25
30–Jun	2	21	45	4	1	0	0	0	73
Total	189	306	598	274	338	44	23	159	1,931

Table 4. Numbers of fish captured by trap 3 in the Kenai River, May 16 through June 30, 1992.

	Numbers of Fish								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
16–May	0	0	3	19	0	0	0	3	25
17–May	0	0	5	5	1	0	0	5	16
18–May	1	0	0	26	0	0	0	2	29
19–May	0	0	1	8	0	0	2	1	12
20–May	0	1	0	10	0	0	0	4	15
21–May	0	7	0	60	0	0	2	7	76
22–May	0	0	1	6	0	0	1	8	16
23–May	0	0	0	1	0	0	0	2	3
24–May	0	1	3	13	0	0	1	1	19
25–May	1	1	1	2	0	0	0	2	7
26–May	1	1	2	1	4	1	4	6	20
27–May	0	0	2	1	7	0	2	2	14
28–May	0	0	0	4	2	1	1	2	10
29–May	0	0	35	0	34	0	8	2	79
30–May	0	9	23	8	29	0	8	7	84
31–May	3	1	32	4	40	5	2	11	98
01–Jun	0	1	35	0	104	0	0	7	147
02–Jun	4	0	31	0	151	3	0	3	192
03–Jun	2	5	5	0	37	0	0	12	61
04–Jun	22	4	10	2	24	0	1	3	66
05–Jun	6	0	37	0	41	6	0	8	98
06–Jun	31	9	10	2	17	1	0	2	72
07–Jun	19	0	6	0	38	3	0	3	69
08–Jun	7	0	6	8	40	2	0	0	63
09–Jun	30	0	11	0	38	0	0	4	83
10–Jun	20	19	14	3	22	3	0	4	85
11–Jun	86	19	26	6	47	0	0	12	196
12–Jun	105	11	19	5	44	0	0	8	192
13–Jun	101	12	134	8	61	2	0	5	323
14–Jun	41	8	116	1	38	4	0	1	209
15–Jun	479	7	19	4	20	0	0	6	535
16–Jun	37	8	50	0	35	0	0	3	133
17–Jun	53	48	33	0	10	6	0	2	152
18–Jun	21	6	23	0	14	0	0	12	76
19–Jun	25	5	7	0	15	0	0	2	54
20–Jun	47	6	44	3	9	0	0	5	114
21–Jun	6	1	11	0	17	0	0	2	37
22–Jun	2	4	45	0	18	2	0	0	71
23–Jun	7	9	9	2	9	0	0	0	36
24–Jun	2	7	18	0	5	0	0	1	33
25–Jun	0	3	101	3	26	0	0	4	137
26–Jun	1	0	39	1	2	0	0	0	43
27–Jun	4	1	19	0	5	2	0	2	33
28–Jun	14	0	86	7	11	5	0	3	126
29–Jun	12	1	29	0	5	0	0	0	47
30–Jun	15	8	97	6	1	0	0	0	127
Total	1,205	223	1,198	229	1,021	46	32	179	4,133

Table 5. Numbers of fish captured by trap 4 in the Kenai River, May 16 through June 30, 1992.

	Numbers of Fish								
Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
16-May	0	0	3	7	0	0	0	9	19
17-May	0	0	5	10	0	0	2	4	21
18-May	0	1	5	26	0	0	0	4	36
19-May	0	2	1	6	0	1	1	7	18
20-May	0	1	1	2	0	0	1	8	13
21-May	0	0	0	11	0	0	3	14	28
22-May	0	0	1	1	0	0	1	3	6
23-May	0	0	1	10	0	0	2	3	16
24-May	0	1	0	2	2	0	0	4	9
25-May	1	0	0	5	0	0	0	6	12
26-May	0	0	2	1	9	0	0	7	19
27-May	0	0	1	1	5	0	0	7	14
28-May	0	0	2	0	5	1	0	4	12
29-May	0	1	31	1	15	0	5	10	63
30-May	2	0	19	0	16	0	1	4	42
31-May	1	0	23	0	65	0	0	11	100
01-Jun	0	0	27	0	86	0	0	4	117
02-Jun	4	0	51	0	215	2	0	12	284
03-Jun	6	0	9	0	70	0	0	9	94
04-Jun	26	0	15	1	113	2	0	6	163
05-Jun	26	0	53	0	180	7	0	7	273
06-Jun	107	1	23	1	66	2	0	6	206
07-Jun	38	0	15	0	118	2	0	4	177
08-Jun	21	0	16	1	162	2	0	6	208
09-Jun	59	0	18	3	154	4	0	9	247
10-Jun	43	0	46	0	107	3	0	20	219
11-Jun	152	5	45	9	79	0	0	20	310
12-Jun	199	10	38	0	78	0	0	7	332
13-Jun	171	8	203	7	83	1	0	11	484
14-Jun	52	1	105	3	72	4	0	4	241
15-Jun	594	7	13	0	51	0	0	4	669
16-Jun	56	3	58	6	22	0	0	3	148
17-Jun	38	8	22	6	9	0	0	4	87
18-Jun	24	2	16	1	27	0	0	4	74
19-Jun	28	2	11	0	18	0	0	5	64
20-Jun	25	9	57	0	12	0	0	5	108
21-Jun	5	0	9	0	12	0	1	3	30
22-Jun	1	4	69	1	33	4	0	2	114
23-Jun	6	2	15	1	6	0	0	0	30
24-Jun	2	2	29	0	14	0	0	2	49
25-Jun	2	5	142	7	15	0	0	4	175
26-Jun	1	0	52	0	10	0	0	1	64
27-Jun	2	0	12	0	5	2	0	0	21
28-Jun	16	3	103	4	28	5	0	2	161
29-Jun	3	1	36	0	5	0	0	0	45
30-Jun	14	3	141	2	1	3	0	0	164
Total	1,725	82	1,544	136	1,968	45	17	269	5,786

Table 6. Numbers of juvenile fish caught with inclined plane traps in the Kenai River, 1990–1992.

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
	Numbers of Fish								
1	47	1,594	500	944	141	117	23	183	3,549
2	189	306	598	274	338	44	23	159	1,931
3	1,205	223	1,198	229	1,021	46	32	179	4,133
4	1,725	82	1,544	136	1,968	45	17	269	5,786
Total	3,166	2,205	3,840	1,583	3,468	252	95	790	15,399
	Percent of Individual Trap Catch								
1	1.3	44.9	14.1	26.6	4.0	3.3	0.6	5.2	100.0
2	9.8	15.8	31.0	14.2	17.5	2.3	1.2	8.2	100.0
3	29.2	5.4	29.0	5.5	24.7	1.1	0.8	4.3	100.0
4	29.8	1.4	26.7	2.4	34.0	0.8	0.3	4.6	100.0
Total	20.6	14.3	24.9	10.3	22.5	1.6	0.6	5.1	100.0
	Percent of Total Catch								
1	0.3	10.4	3.2	6.1	0.9	0.8	0.1	1.2	23.0
2	1.2	2.0	3.9	1.8	2.2	0.3	0.1	1.0	12.5
3	7.8	1.4	7.8	1.5	6.6	0.3	0.2	1.2	26.8
4	11.2	0.5	10.0	0.9	12.8	0.3	0.1	1.7	37.6
Total	20.6	14.3	24.9	10.3	22.5	1.6	0.6	5.1	100.0
1990	Percent of Total Catch								
1	6.2	0.3	0.6	0.2		0.1	0.0	0.1	7.5
2	12.8	0.1	0.8	0.2		0.1	0.0	0.1	14.1
3	42.2	0.5	2.0	0.2		0.1	0.1	0.1	45.1
4	30.8	0.0	2.2	0.1		0.0	0.0	0.2	33.4
Total	92.0	1.0	5.6	0.6		0.2	0.1	0.5	100.0
1991	Percent of Total Catch								
1	5.2	0.2	1.3	0.4	0.3	0.1		0.5	8.0
2	9.8	0.1	2.7	0.3	0.7	0.1		0.5	14.2
3	31.4	0.1	4.5	0.2	2.3	0.0		0.6	39.1
4	30.5	0.1	5.0	0.2	2.5	0.0		0.5	38.8
Total	76.9	0.5	13.5	1.1	5.8	0.2		2.1	100.1

Table 7. Numbers of sockeye salmon smolt captured daily in the Kenai River, 1989–1992.

Date	Year 1989 [a]	1990	1991	1992	Date	Year 1989 [a]	1990	1991	1992
15–May		8			16–Jun	2,197	165	279	100
16–May	348	5	4	0	17–Jun	1,369	123	182	99
17–May	155	34	4	0	18–Jun	607	17	24	49
18–May	204	376	1	1	19–Jun	972	36	658	57
19–May	195	507	1	0	20–Jun	952	186	2,252	94
20–May	454	3,159	8	0	21–Jun	1,036	168	1,971	16
21–May	271	4,760	13	0	22–Jun	639	108	2,446	3
22–May	716	2,690	36	0	23–Jun	2,835	37	923	14
23–May	1,546	414	680	0	24–Jun	1,833	20	407	5
24–May	1,184	282	389	0	25–Jun	660	56	377	2
25–May	988	1,645	319	2	26–Jun	679		2,972	2
26–May	785	16,411	622	1	27–Jun	486		263	6
27–May	2,699	8,057	306	0	28–Jun			320	40
28–May	2,056	1,903	151	1	29–Jun			213	18
29–May	1,532	1,745	414	1	30–Jun			122	31
30–May	2,268	9,578	502	2	01–Jul			517	
31–May	6,257	9,878	494	5	02–Jul			19	
01–Jun	8,221	3,305	284	1	03–Jul			239	
02–Jun	2,697	2,587	904	9	04–Jul			494	
03–Jun	4,350	8,037	459	9	05–Jul			10	
04–Jun	10,170	10,182	414	56	06–Jul			32	
05–Jun	17,579	14,143	440	35	07–Jul			30	
06–Jun	49,451	8,931	262	144	08–Jul			40	
07–Jun	16,276	8,337	579	69	09–Jul			33	
08–Jun	3,482	4,430	633	28	10–Jul			6	
09–Jun	3,271	6,336	492	94					
10–Jun	2,188	429	699	69	TOTAL	161,111	129,868	28,173	3,166
11–Jun	988	261	525	250					
12–Jun	1,656	248	825	329					
13–Jun	1,044	93	1,296	300					
14–Jun	3,052	51	934	101					
15–Jun	763	131	654	1,123					

[a] Three traps were fished in 1989; four traps were fished in the remaining years.

Table 8. Dyed sockeye salmon smolt releases and recaptures by date.

Month	Day	Time	Trap Number	Number of Fish Dyed	Number of Dyed Fish Released	Capture to Release Survival [a]	Number Dyed Fish Recovered	Trap Efficiency
6	13			329	260	0.790		
6	13	410	1				3	
6	13	425	2				1	
6	13	445	3				4	
6	13	515	4				1	0.035
6	14			242	138	0.570		
6	14	2,335	1					
6	14	2,340	2					
6	14	2,350	3					
6	14	2,359	4				2	0.014
6	15			931	451	0.484		
6	15	350	1				2	
6	15	355	2				0	
6	15	400	3				3	
6	15	420	4				1	0.013
6	18			97	77	0.794		
6	18	130	3				1	
6	18	405	4				0	
6	18	408	3				0	
6	18	414	2				1	
6	18	425	1				0	0.026
Total				1,599	926	0.579	19	0.021

[a] Number of dyed fish released/Number of dyed fish.

Table 9. Results of sockeye salmon smolt dye tests conducted on the Kenai River, 1989–1992.

Date	Number of Fish Dyed	Number of Dyed Fish Recovered	Trap Efficiency
1989 total	12,599	86	0.007
1990 period 1	2,793	21	0.008
1990 period 2–4	8,409	109	0.013
1990 total	11,202	130	0.012
1991 total	1,923	19	0.010
1992 total	926	19	0.021
1989–91 Total	25,724	235	0.009

Table 10. Estimated daily sockeye salmon smolt seaward migration from the Kenai River, 1992.

Date	Daily Sockeye Smolt Trap Catch	Estimate of Sockeye Smolt Migration [a]			
		Daily	Cumulative	age-1.0	age-2.0
16-May	0	0	0	0	0
17-May	0	0	0	0	0
18-May	1	119	119	19	100
19-May	0	0	119	0	0
20-May	0	0	119	0	0
21-May	0	0	119	0	0
22-May	0	0	119	0	0
23-May	0	0	119	0	0
24-May	0	0	119	0	0
25-May	2	238	358	38	200
26-May	1	119	477	19	100
27-May	0	0	477	0	0
28-May	1	119	596	19	100
29-May	1	119	715	19	100
30-May	2	238	954	38	200
31-May	5	596	1,550	96	500
01-Jun	1	119	1,669	19	100
02-Jun	9	1,073	2,742	173	900
03-Jun	9	1,073	3,814	173	900
04-Jun	56	6,675	10,490	1,075	5,601
05-Jun	35	4,172	14,662	672	3,500
06-Jun	144	17,165	31,827	2,764	14,402
07-Jun	69	8,225	40,052	1,324	6,901
08-Jun	28	3,338	43,390	537	2,800
09-Jun	94	11,205	54,595	1,804	9,401
10-Jun	69	8,225	62,820	1,324	6,901
11-Jun	250	29,801	92,621	3,278	26,523
12-Jun	329	39,218	131,839	4,314	34,904
13-Jun	300	35,761	167,600	3,934	31,827
14-Jun	101	12,040	179,639	1,324	10,715
15-Jun	1,123	133,865	313,504	14,725	119,140
16-Jun	100	11,920	325,424	5,126	6,795
17-Jun	99	11,801	337,226	5,074	6,727
18-Jun	49	5,841	343,067	2,512	3,329
19-Jun	57	6,795	349,861	2,922	3,873
20-Jun	94	11,205	361,066	4,818	6,387
21-Jun	16	1,907	362,973	820	1,087
22-Jun	3	358	363,331	154	204
23-Jun	14	1,669	365,000	718	951
24-Jun	5	596	365,596	256	340
25-Jun	2	238	365,834	103	136
26-Jun	2	238	366,073	103	136
27-Jun	6	715	366,788	308	408
28-Jun	40	4,768	371,556	2,050	2,718
29-Jun	18	2,146	373,702	923	1,223
30-Jun	31	3,695	377,397	1,589	2,106
Total	3,166	377,397		65,163	312,234

[a] Total migration – 377,397; Variance – 7.66E+9. Lower confidence interval – 246,468; Upper confidence interval – 469,175.

Table 11. Cumulative proportion of sockeye salmon smolt seaward migration by day, 1989–1992.

Date	Age–1.0				Age–2.0		
	1989	1990	1991	1992	1990	1991	1992
15–May		0.000			0.000		
16–May	0.002	0.000	0.000	0.000	0.000	0.001	0.000
17–May	0.003	0.000	0.000	0.000	0.001	0.002	0.000
18–May	0.004	0.004	0.000	0.000	0.007	0.002	0.000
19–May	0.006	0.008	0.000	0.000	0.015	0.002	0.000
20–May	0.008	0.036	0.000	0.000	0.067	0.004	0.000
21–May	0.010	0.078	0.000	0.000	[a] 0.146	0.007	0.000
22–May	0.015	0.101	0.000	0.000	0.190	0.015	0.000
23–May	0.024	0.105	0.003	0.000	0.197	0.169	0.000
24–May	0.031	0.106	0.005	0.000	0.200	0.256	0.000
25–May	0.038	0.112	0.007	0.001	0.217	0.328	0.001
26–May	0.042	0.169	0.010	0.001	0.387	0.469	0.001
27–May	0.059	0.197	0.011	0.001	0.471	0.538	0.001
28–May	0.072	0.204	0.015	0.001	0.490	0.550	0.002
29–May	0.082	0.216	0.027	0.002	0.503	0.583	0.002
30–May	0.096	0.282	0.041	0.002	0.574	0.624	0.003
31–May	0.134	0.350	0.055	0.004	0.647	0.664	0.004
01–Jun	0.185	0.373	0.063	0.004	0.672	0.687	0.004
02–Jun	0.202	0.391	0.089	0.007	0.691	0.759	0.007
03–Jun	0.229	0.469	0.102	0.009	0.730	0.797	0.010
04–Jun	0.292	0.569	0.113	0.026	0.781	0.830	0.028
05–Jun	0.401	0.706	0.126	0.036	0.851	0.865	0.039
06–Jun	0.708	0.793	0.133	0.079	0.895	0.887	0.086
07–Jun	0.809	0.874	0.155	0.099	0.936	0.898	0.108
08–Jun	0.831	0.918	0.179	0.107	0.958	0.910	0.117
09–Jun	0.851	0.979	0.198	0.135	0.989	0.919	0.147
10–Jun	0.865	0.983	0.225	0.155	0.992	0.933	0.169
11–Jun	0.871	0.986	0.245	0.206	0.993	0.943	0.254
12–Jun	0.881	0.988	0.277	0.272	0.994	0.950	0.366
13–Jun	0.888	0.989	0.329	0.332	0.995	0.962	0.467
14–Jun	0.907	0.990	0.366	0.352	0.995	0.970	0.502
15–Jun	0.911	0.991	0.392	0.578	0.995	0.976	0.883
16–Jun	0.925	0.993	0.403	0.657	0.996	0.979	0.905
17–Jun	0.934	0.994	0.411	0.735	0.997	0.980	0.927
18–Jun	0.937	0.994	0.412	0.773	0.997	0.980	0.937
19–Jun	0.943	0.994	0.438	0.818	0.997	0.983	0.950
20–Jun	0.949	0.996	0.530	0.892	0.998	0.991	0.970
21–Jun	0.956	0.998	0.610	0.905	0.999	0.998	0.974
22–Jun	0.960	0.999	0.711	0.907	0.999	0.998	0.974
23–Jun	0.977	0.999	0.749	0.918	1.000	0.999	0.977
24–Jun	0.989	0.999	0.766	0.922	1.000	0.999	0.978
25–Jun	0.993	1.000	0.781	0.924	1.000	0.999	0.979
26–Jun	0.997		0.904	0.925		0.999	0.979
27–Jun	1.000		0.914	0.930		1.000	0.981
28–Jun			0.928	0.961		1.000	0.989
29–Jun			0.936	0.976		1.000	0.993
30–Jun			0.941	1.000		1.000	1.000
01–Jul			0.963			1.000	
02–Jul			0.964			1.000	
03–Jul			0.973			1.000	
04–Jul			0.994			1.000	
05–Jul			0.994			1.000	
06–Jul			0.996			1.000	
07–Jul			0.997			1.000	
08–Jul			0.998			1.000	
09–Jul			1.000			1.000	
10–Jul			1.000			1.000	

[a] Shaded blocks highlight .1 proportion increments

Table 12. Summary of Kenai River sockeye salmon smolt age composition, 1989–1992. Data collected at river km 31.

Sample Period	Percent of Seaward Migration			Sample Size
	Age–1.	Age–2.	Age–3.	
5/15–5/23/90	31.9	68.1	0.0	756
5/24–5/28/90	22.8	76.7	0.5	427
5/29–6/2/90	45.0	54.7	0.3	424
6/3–6/25/90	63.4	36.6	0.0	1,815
5/16–5/27/91	11.3	88.5	0.2	425
5/28–6/6/91	68.4	31.6	0.0	850
6/7–6/11/91	92.5	7.5	0.0	425
6/12–6/17/91	96.5	3.5	0.0	425
6/18–6/21/91	98.6	1.4	0.0	425
6/22–7/15/91	99.9	0.1	0.0	1,190
5/16–6/10/92	16.1	83.9	0.0	348
6/11–6/15/92	11.0	89.0	0.0	319
6/16–6/30/92	43.0	57.0	0.0	314
Season Summary				
1989	99.7	0.3	0.0	3,557
1990	46.7	53.1	0.2	3,422
1991	86.1	13.9	0.0	3,740
1992	17.3	82.7	0.0	981

Table 13. Sockeye salmon smolt mean length and weight by age class and time strata, 1989–1992. Data collected at river km 31.

			Length						Weight					
Year	Time Period	Age	N	Mean	Min.	Max.	Var.	Stand. Dev.	N	Mean	Min.	Max.	Var.	Stand. Dev.
89	5/16–20	1.	413	60	46	80	19	4	413	1.9	0.8	4.3	0.18	0.42
89	5/21–25	1.	338	61	60	72	22	5	338	2.1	1.2	3.3	0.13	0.38
89	5/26–30	1.	421	60	53	77	17	4	421	1.9	1.2	3.8	0.15	0.39
89	5/31–6/04	1.	424	59	49	70	13	4	424	1.8	1.0	3.4	0.13	0.36
89	6/06–09	1.	423	59	46	73	15	4	424	1.8	0.8	3.7	0.15	0.39
89	6/10–14	1.	425	58	49	74	14	4	425	1.8	1.1	3.5	0.12	0.35
89	6/15–6/19	1.	429	58	46	75	17	4	429	1.8	0.2	4.0	0.20	0.45
89	6/20–27	1.	679	60	19	85	19	4	679	2.1	1.0	5.4	0.26	0.51
90	5/15–23	1.	241	65	48	82	30	5	241	2.2	1.0	4.2	0.34	0.59
90	5/24–28	1.	97	63	52	78	25	5	97	2.0	1.0	3.8	0.27	0.52
90	5/29–6/02	1.	191	61	47	90	25	5	191	1.9	0.8	5.3	0.28	0.53
90	6/03–25	1.	1,150	70	52	138	53	7	1,150	3.1	1.0	23.8	2.17	1.47
91	5/23–27	1.	48	73	52	110	92	10	48	3.4	1.8	10.4	2.15	1.47
91	5/28–6/01	1.	292	65	52	89	41	6	292	2.3	1.1	5.5	0.55	0.74
91	6/02–06	1.	289	67	55	100	44	7	289	2.5	1.3	7.4	0.75	0.86
91	6/07–11	1.	393	64	50	79	16	4	393	2.4	1.2	4.8	0.22	0.46
91	6/13–17	1.	410	65	49	84	16	4	410	2.7	1.2	5.9	0.31	0.56
91	6/18–21	1.	419	65	50	79	21	5	419	2.8	1.3	5.6	0.40	0.63
91	6/22–25	1.	340	66	50	84	19	4	340	2.9	1.3	5.6	0.34	0.58
91	6/26–30	1.	424	65	50	75	11	3	424	2.7	1.2	4.3	0.21	0.46
91	7/01–05	1.	425	67	54	80	13	4	425	3.1	1.5	5.9	0.31	0.55
92	6/05–10	1.	56	74	60	90	54	7	28	3.9	2.5	6.3	1.21	1.10
92	6/11–15	1.	35	78	66	95	35	6	17	5.1	3.2	10.7	3.03	1.74
92	6/16–29	1.	135	78	58	130	86	9	97	4.7	1.9	22.0	5.33	2.31
90	5/15–23	2.	515	74	62	123	21	5	515	3.2	1.9	13.4	0.55	0.74
90	5/24–28	2.	326	74	61	115	35	6	326	3.2	1.8	8.8	0.68	0.82
90	5/29–6/02	2.	232	74	62	104	43	7	232	3.2	1.2	8.9	1.12	1.06
90	6/03–25	2.	665	75	60	102	28	5	665	3.7	1.8	7.8	0.71	0.84
91	5/23–27	2.	376	80	71	108	29	5	376	4.2	2.8	10.7	1.07	1.03
91	5/28–6/01	2.	133	79	70	101	32	6	133	4.1	3.0	8.9	1.01	1.01
91	6/02–06	2.	136	79	68	110	41	6	136	4.2	2.5	10.1	1.30	1.14
91	6/07–11	2.	32	78	70	91	25	5	32	4.1	2.4	6.3	0.85	0.92
91	6/13–17	2.	15	76	68	86	20	4	15	4.0	3.3	5.2	0.29	0.54
92	6/05–10	2.	292	97	71	117	62	8	151	7.7	3.3	11.2	2.73	1.65
92	6/11–15	2.	284	89	76	110	22	5	156	6.9	4.3	10.4	1.08	1.04
92	6/16–29	2.	179	89	69	111	20	4	134	6.5	3.2	12.0	1.16	1.08

Table 14. Morphological information collected from age−2. sockeye salmon smolt captured in the Russian and Moose Rivers, 1992.

		Russian River	Moose River
	N =	297	233
	Percent of Catch =	99.0	89.3
Length (mm)			
	Mean =	100	122
	Range =	76−115	80−165
	Variance =	46	139
	Standard Deviation =	7	12
Weight (g)			
	Mean =	9.9	18.2
	Range =	4.2−14.4	5.0−40.3
	Variance =	2.98	24.05
	Standard Deviation =	1.73	4.91

Table 15. Water parameters measured daily at the Kenai River km 31 sockeye salmon smolt enumeration site, 1992.

Date	Level Reading (cm)	Level Change (cm)	Turbidity Reading (cm)	Turbidity Change (cm)	Temperature (°c)	Velocity (fps) Trap 1	Trap 2	Trap 3	Trap 4
16–May	27	0	137	0	6	2.7	2.5	2.4	2.3
17–May	27	0	135	−3	7				
18–May	28	1	137	3	6				
19–May	29	1	137	0	9				
20–May	30	2	145	8	9				
21–May	32	1	137	−8	10				
22–May	35	3	127	−10	10				
23–May	40	5	109	−18	10	3.2	2.8	2.8	3.2
24–May	41	2	122	13	12				
25–May	47	6	99	−23	11	3.2	3.5	3.2	3.6
26–May	55	8	81	−18	10	3.2	3.2	3.5	3.8
27–May	64	9	69	−13	11				
28–May	67	3	69	0	9				
29–May	73	6	53	−15	10	4.5	4.2	4	4.2
30–May	82	9	61	8	10	4.8	5	4.8	4.8
31–May	88	6	74	13	10	3.9	4.4	4.5	4.3
01–Jun	91	3	61	−13	11	4.7	5	4.8	4.7
02–Jun	98	6	89	28	10	4.7	4.8	4.6	4.9
03–Jun	101	3	84	−5	11				
04–Jun	104	3	89	5	10				
05–Jun	104	1	99	10	11				
06–Jun	107	2	97	−3	11	4.4	4.5	4.3	4.7
07–Jun	110	3	81	−15	10				
08–Jun	113	3	86	5	11				
09–Jun	110	−3	107	20	9				
10–Jun	110	0	102	−5	10	3.8	5.2	5	5.2
11–Jun	113	3	97	−5	13				
12–Jun	113	0	81	−15	10				
13–Jun	119	6	74	−8	14				
14–Jun	122	3	66	−8	12	5.4	5.4	5.4	5.4
15–Jun	123	2	64	−3	12				
16–Jun	125	2	74	10	12				
17–Jun	123	−2	94	20	9				
18–Jun	122	−2	79	−15	12				
19–Jun	123	2	84	5	13				
20–Jun	122	−2	97	13	13				
21–Jun	119	−3	94	−3	10				
22–Jun	119	0	86	−8	14				
23–Jun	119	0	104	18	13	5	5	5	5.1
24–Jun	116	−3	130	25	11				
25–Jun	116	0	97	−33	12				
26–Jun	114	−2	97	0	12				
27–Jun	116	2	104	8	12				
28–Jun	114	−2	89	−15	12				

Table 16. Summary of results of inanimate object release studies to examine sockeye salmon smolt trap efficiencies in the Kenai River, 1992.

	Number Released at Each Location			Recoveries by trap																													
				Trap 1						Trap 2						Trap 3						Trap 4						Total – All Traps					
	North Bank	Mid-River	South Bank	North Bank		Mid-river		South Bank		North Bank		Mid-river		South Bank		North Bank		Mid-river		South Bank		North Bank		Mid-river		South Bank		North Bank		Mid-river		South Bank	
Date	No.	No.	No.	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion	No.	Proportion
20–May	2,000	2,000	2,000	0	0.000	44	0.022	64	0.032	0	0.000	96	0.048	111	0.056	0	0.000	31	0.016	30	0.015	2	0.001	110	0.055	83	0.042	2	0.001	281	0.141	288	0.144
27–May			2,000					71	0.036					60	0.030					25	0.013					31	0.016					187	0.094
03–Jun	2,000	2,000	2,000	4	0.002	288	0.144	108	0.054	1	0.001	97	0.049	38	0.019	0	0.000	26	0.013	21	0.011	1	0.001	41	0.021	11	0.006	6	0.003	452	0.226	178	0.089
10–Jun			2,000					163	0.082					66	0.033					18	0.009					19	0.010					266	0.133
17–Jun	2,000	2,000	2,000	14	0.007	178	0.089	64	0.032	3	0.002	52	0.026	25	0.013	2	0.001	22	0.011	22	0.011	2	0.001	17	0.009	12	0.006	21	0.011	269	0.135	123	0.062
24–Jun			2,000					170	0.085					69	0.035					33	0.017					39	0.020					311	0.156
Total	6,000	6,000	12,000	18	0.003	510	0.085	640	0.053	4	0.001	245	0.041	369	0.031	2	0.000	79	0.013	149	0.012	5	0.001	168	0.028	195	0.016	29	0.005	1,002	0.167	1,353	0.113

[a] Estimated 500–600 north bank release, 200 south bank release, and 50 mid–river release radishes found in eddies above the traps on 6/4, 1500 h.

Table 17. Sockeye salmon adult escapement and smolt production in the Kenai River, 1986–1992.

Brood Year	Total Spawning Escapement	Number of Smolt Produced Age–1.	Age–2.	Age–3.	Total	Smolt per Spawner
1986	422,000	[a]	72,000	16,000		
1987	1,408,000	23,804,000	5,758,000	1,000	29,563,000	21.0
1988	910,000	5,069,000	418,000	0	5,487,000	6.0
1989	1,379,000	2,582,000	312,000[b]	[c]	2,894,000	2.1
1990	519,000	253,000[b]	[c]			
1991	431,000					
1992	798,000					

[a] No data collected.

[b] Includes Hidden Lake and Moose River stocks.

[c] Migrate as smolt in 1993.

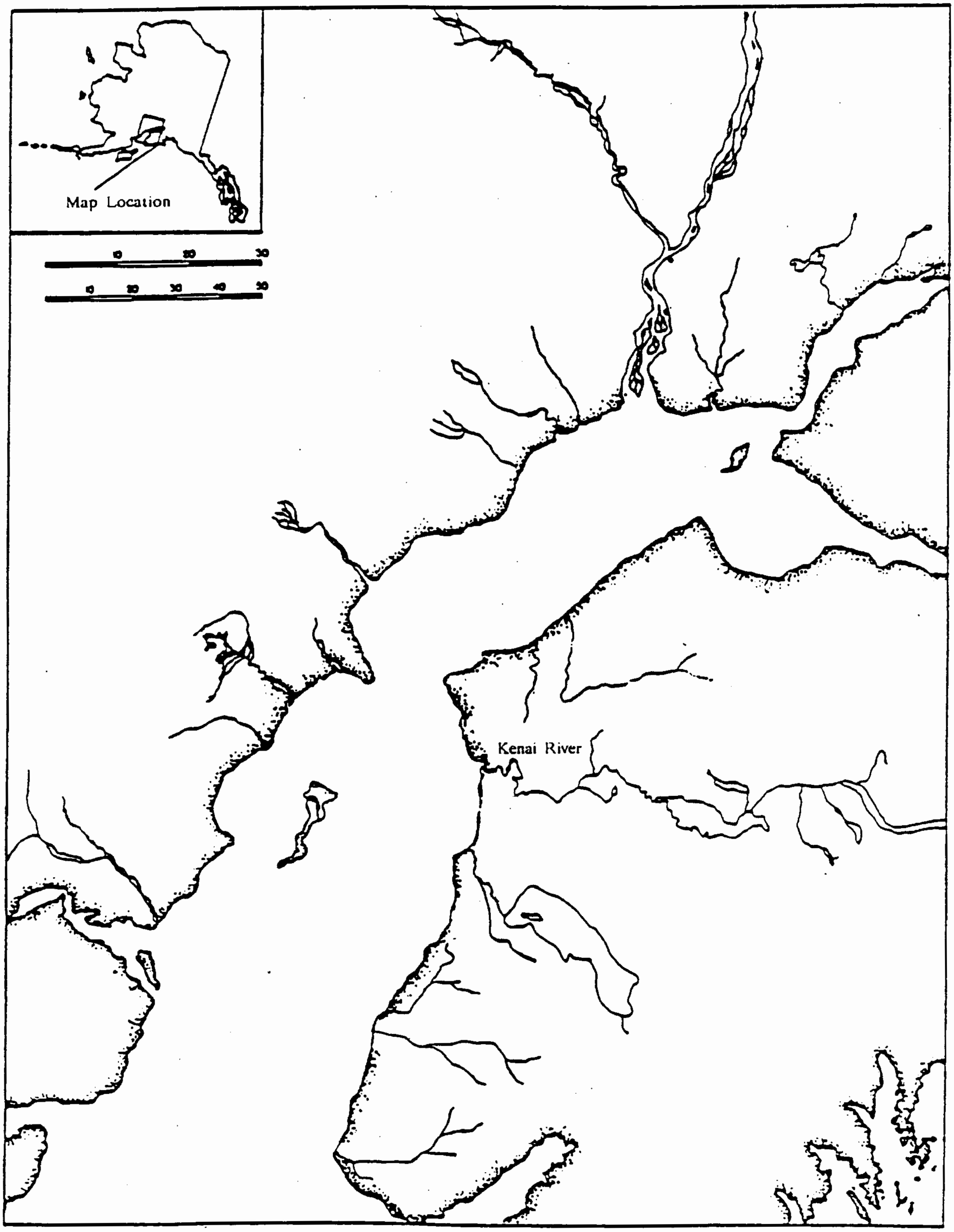


Figure 1. Location of the Kenai River in Upper Cook Inlet, Alaska.

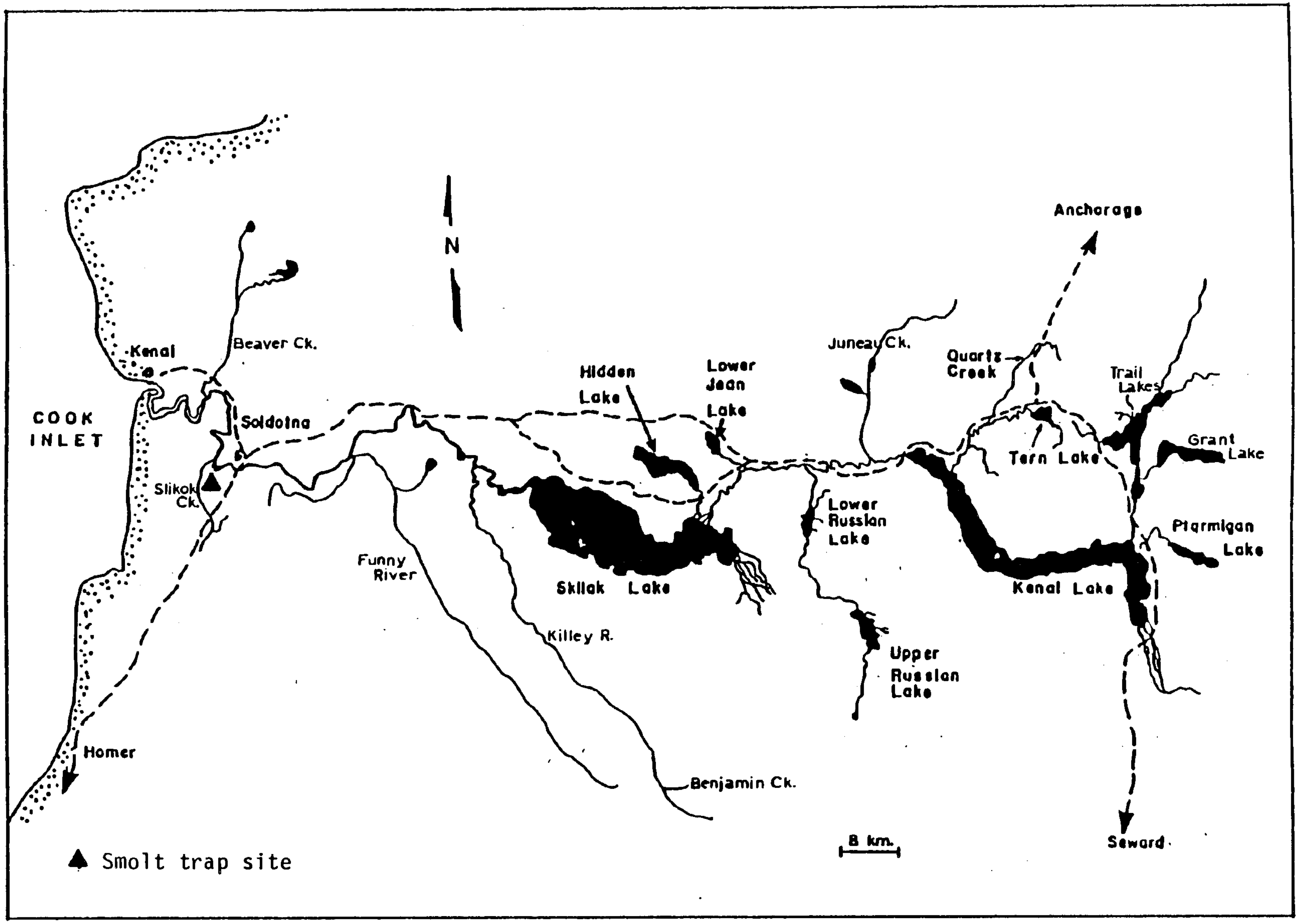


Figure 2. Kenai River drainage and major sockeye salmon rearing lakes.

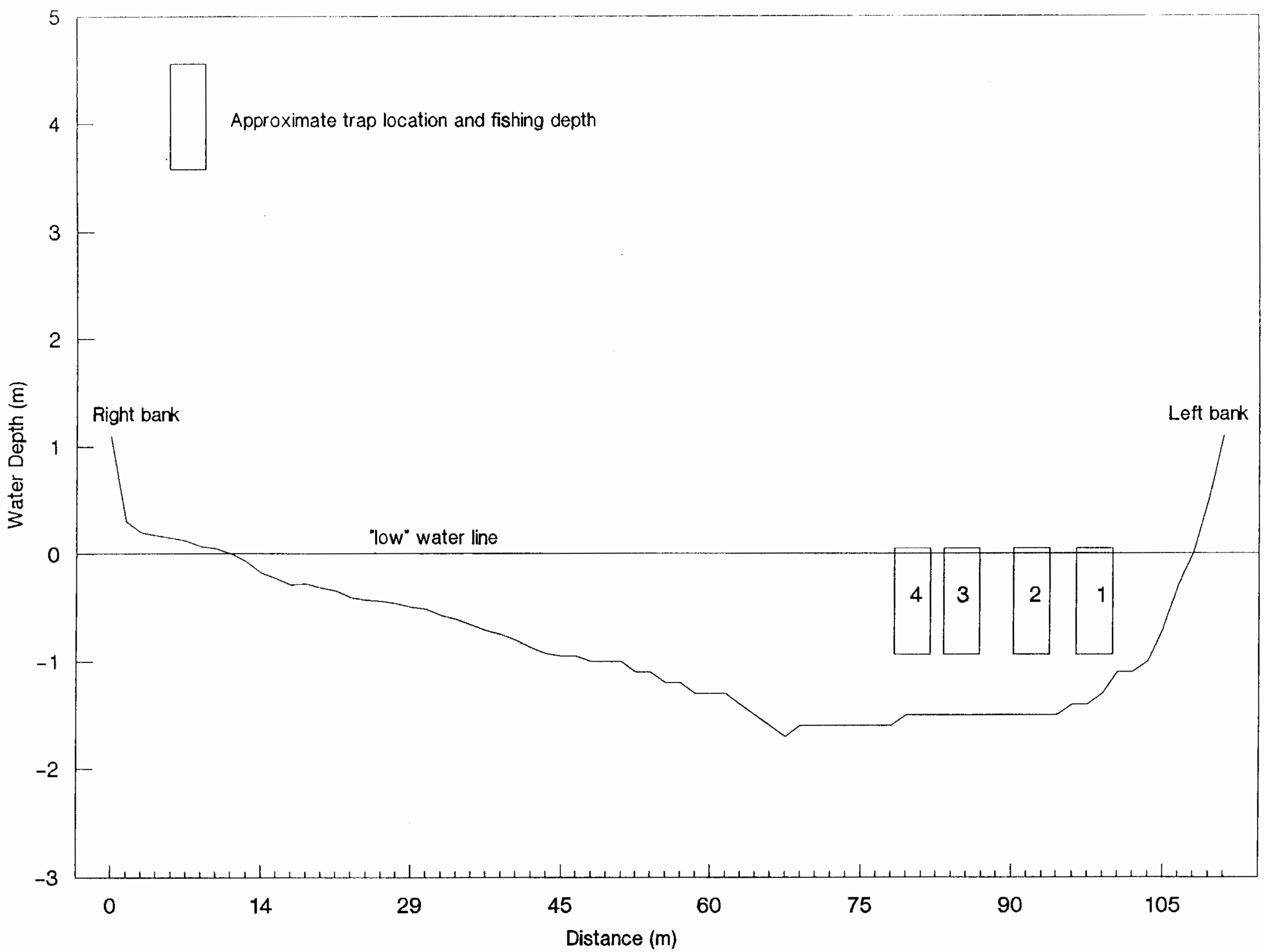


Figure 3. River bottom configuration and trap location at the Kenai River sockeye salmon smolt enumeration site (river km 31), 1992.

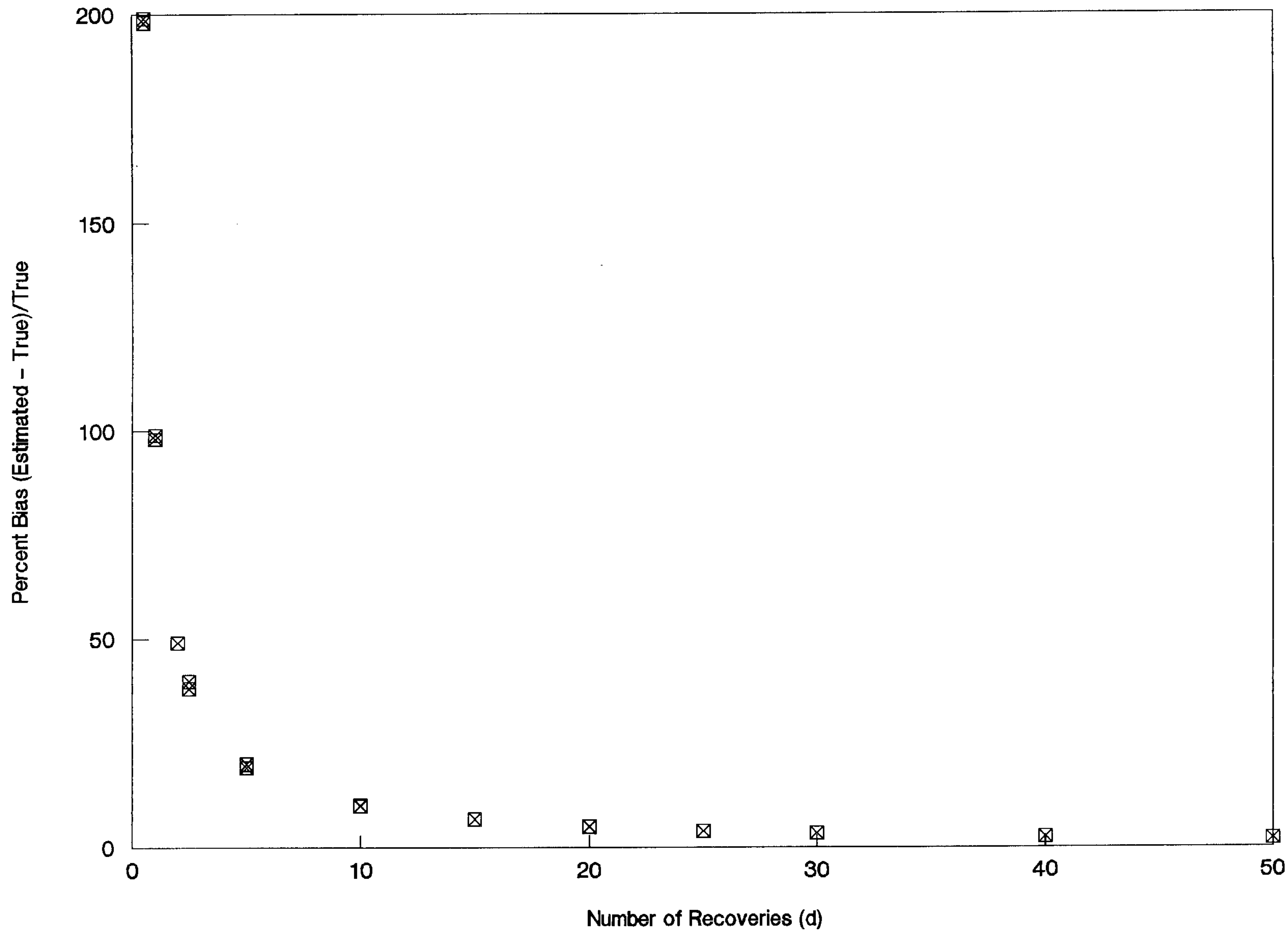


Figure 4. The potential bias in the estimation of population size as a function of the number of recoveries in a mark-recapture estimate.

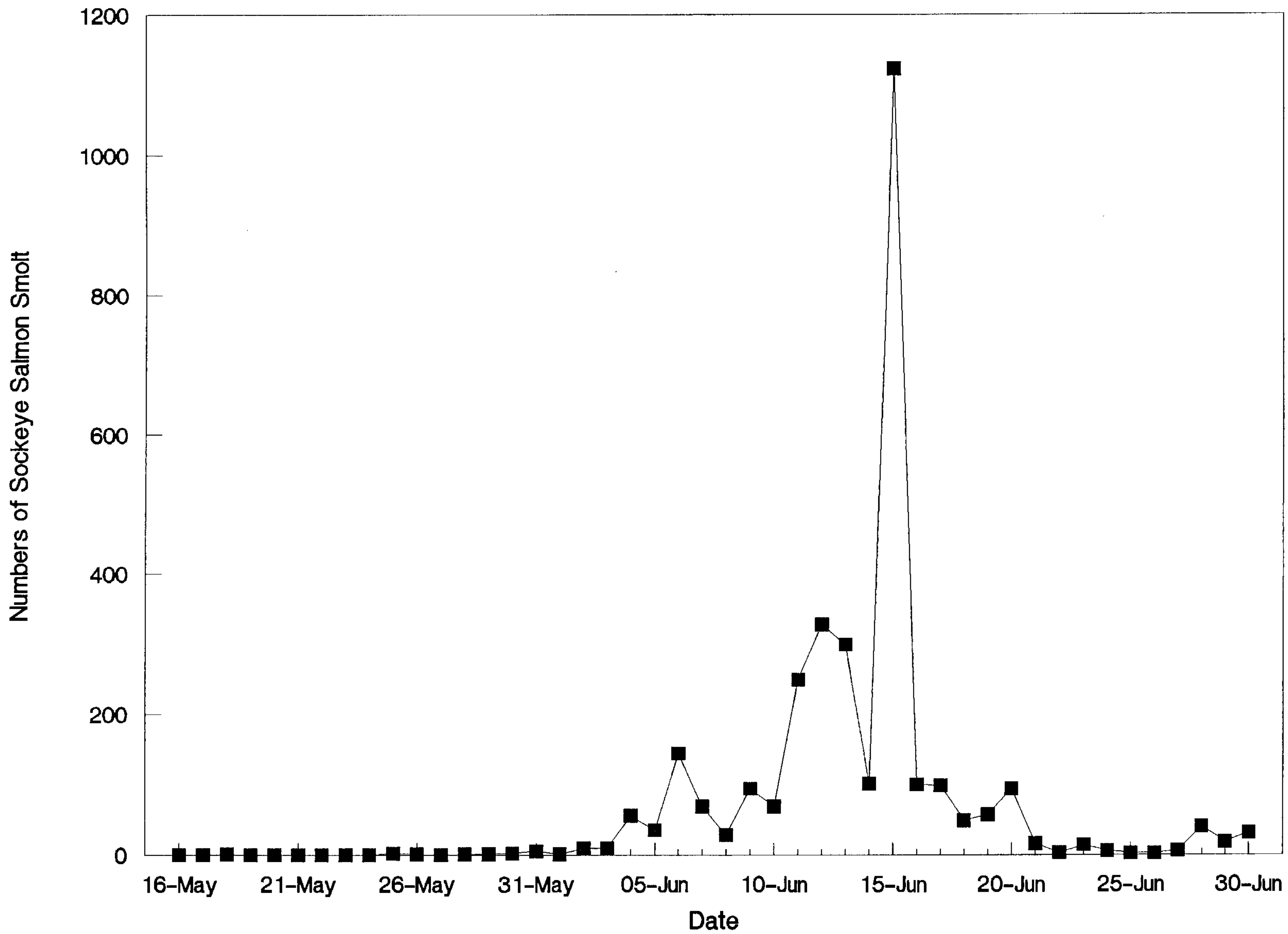
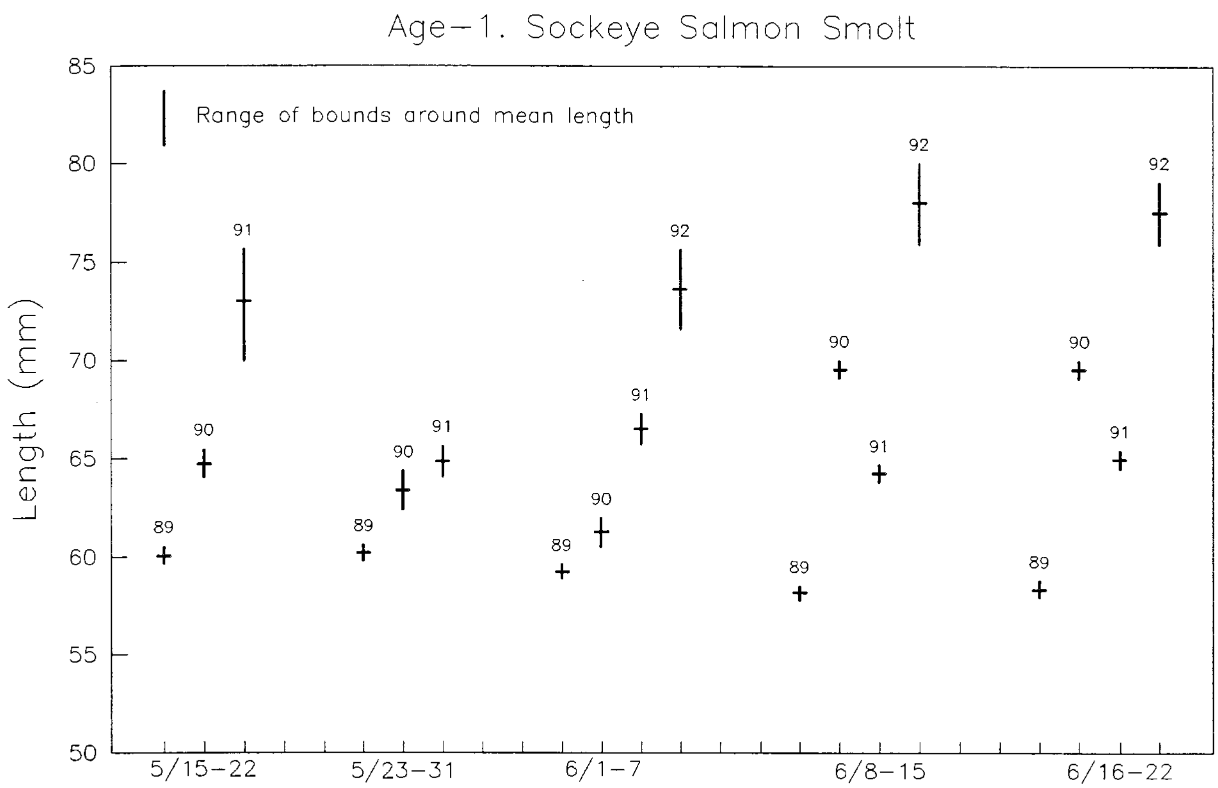


Figure 5. Daily numbers of sockeye salmon smolt migrating seaward from the Kenai River, 1992.



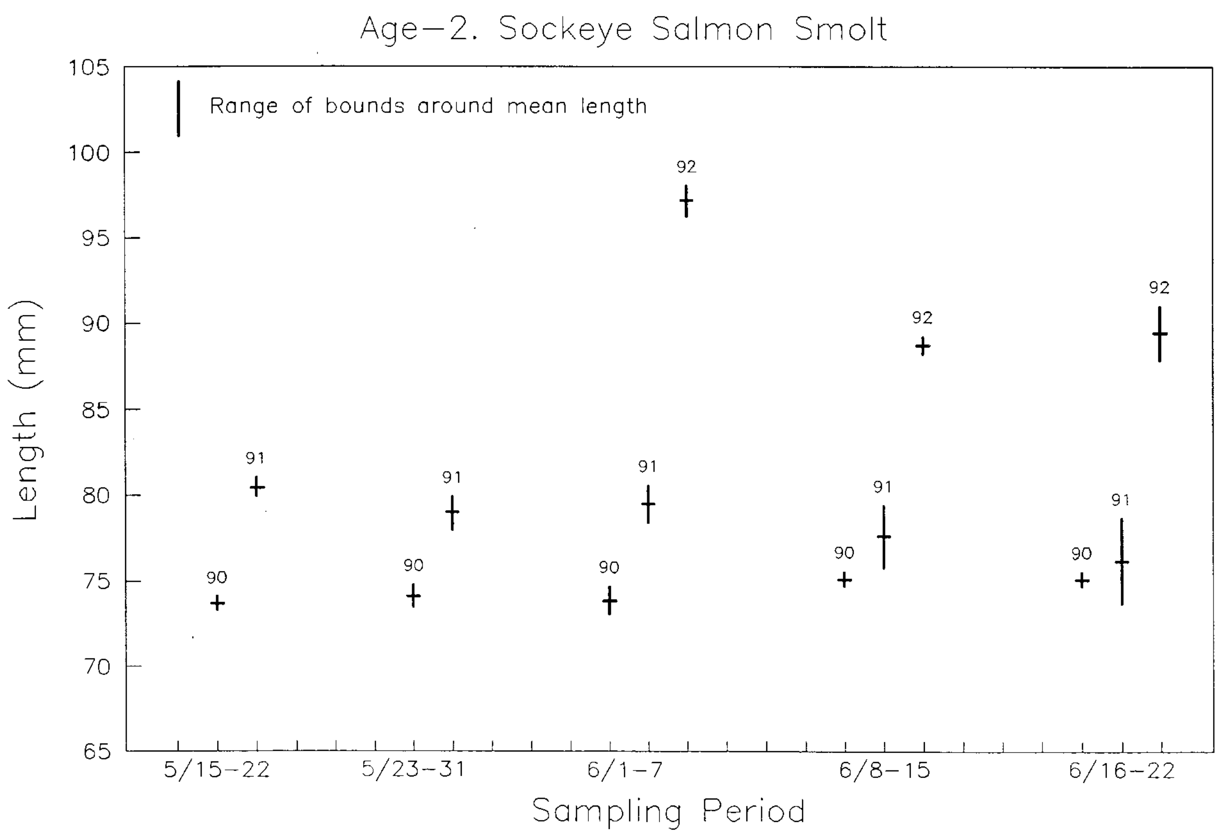


Figure 6. Mean lengths and 95% confidence bounds for age-1. and -2. sockeye salmon sampled at the Kenai River (km 31) smolt enumeration site, 1989-1992.

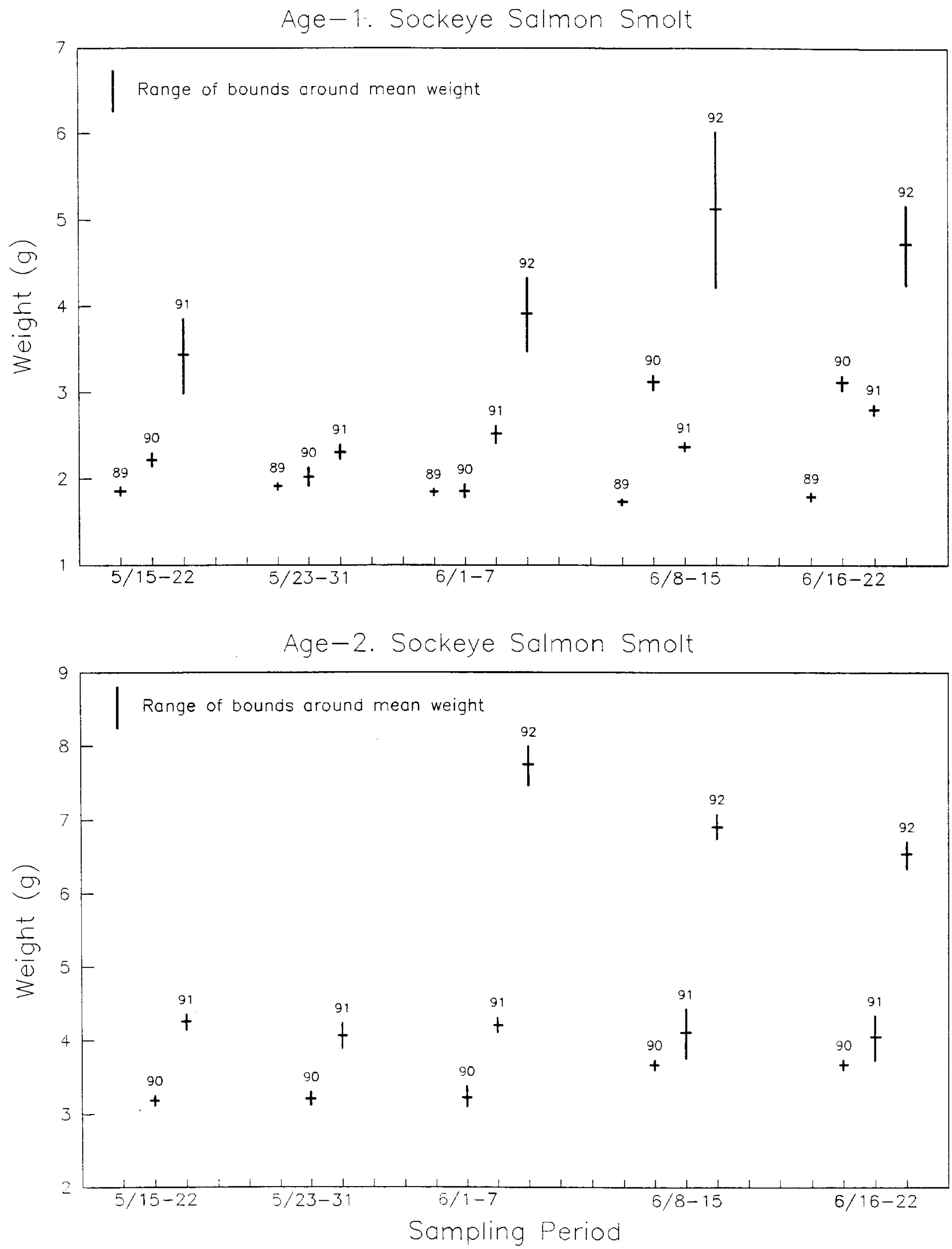


Figure 7. Mean weights and 95% confidence bounds for age-1. and 2. sockeye salmon sampled at the Kenai River (km 31) smolt enumeration site, 1989-1992.

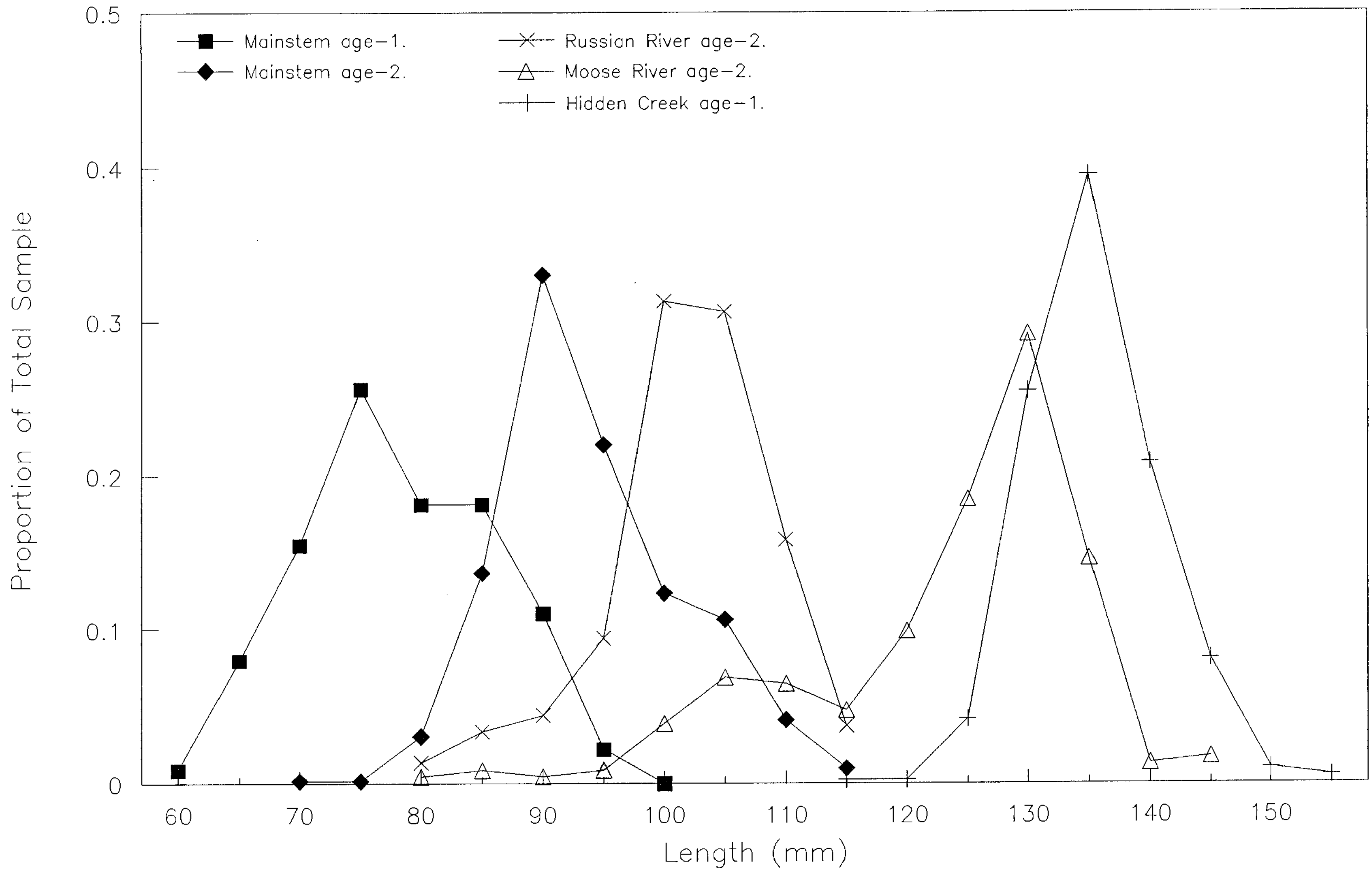


Figure 8. Length frequency distribution of sockeye salmon smolt captured in the mainstem (km 31) Kenai, Russian, and Moose Rivers and Hidden Creek (Fandrei 1992), 1992.

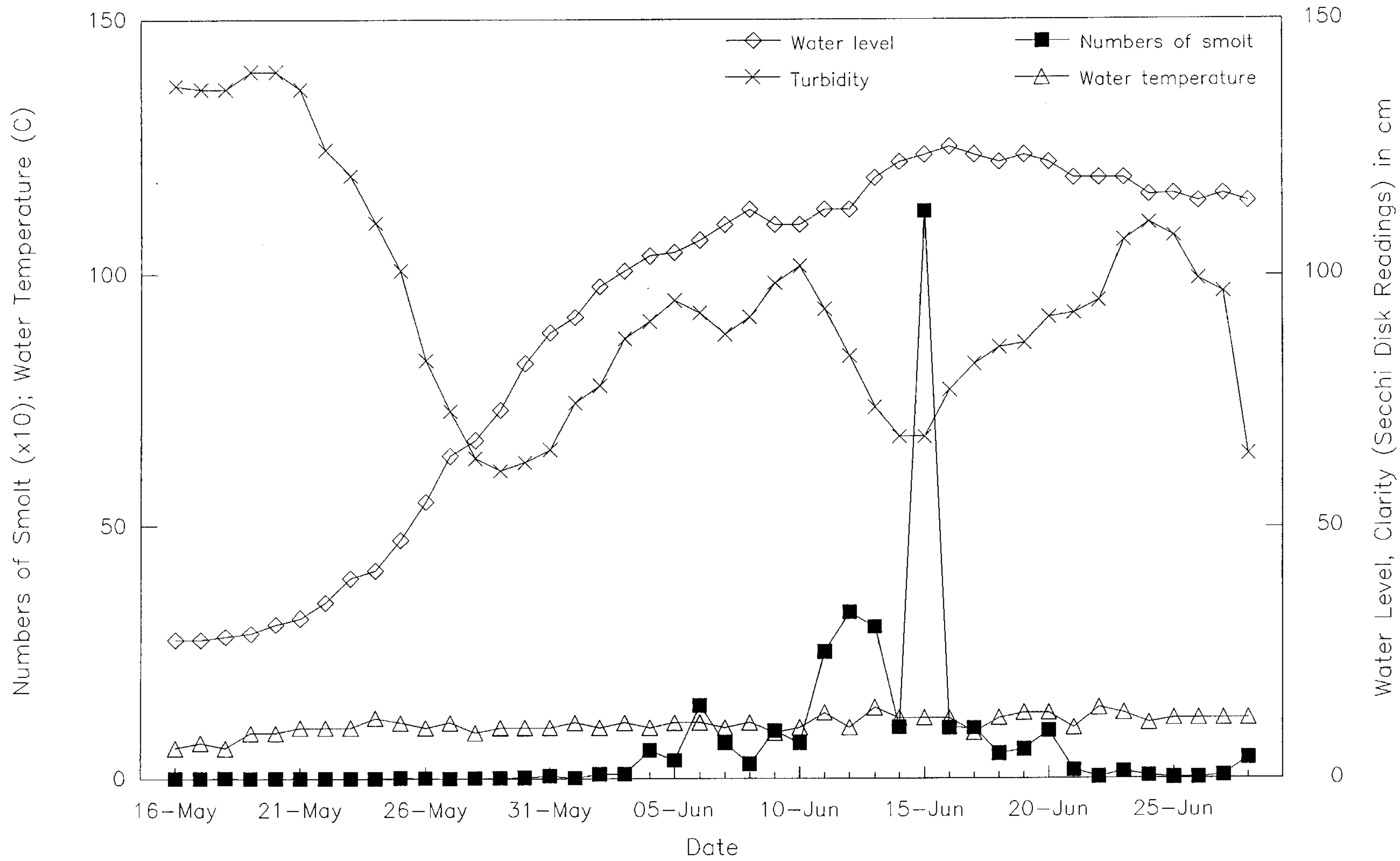


Figure 9. Daily numbers of sockeye salmon smolt migrating seaward, and physical characteristics measured at the Kenai River km 31 enumeration site.

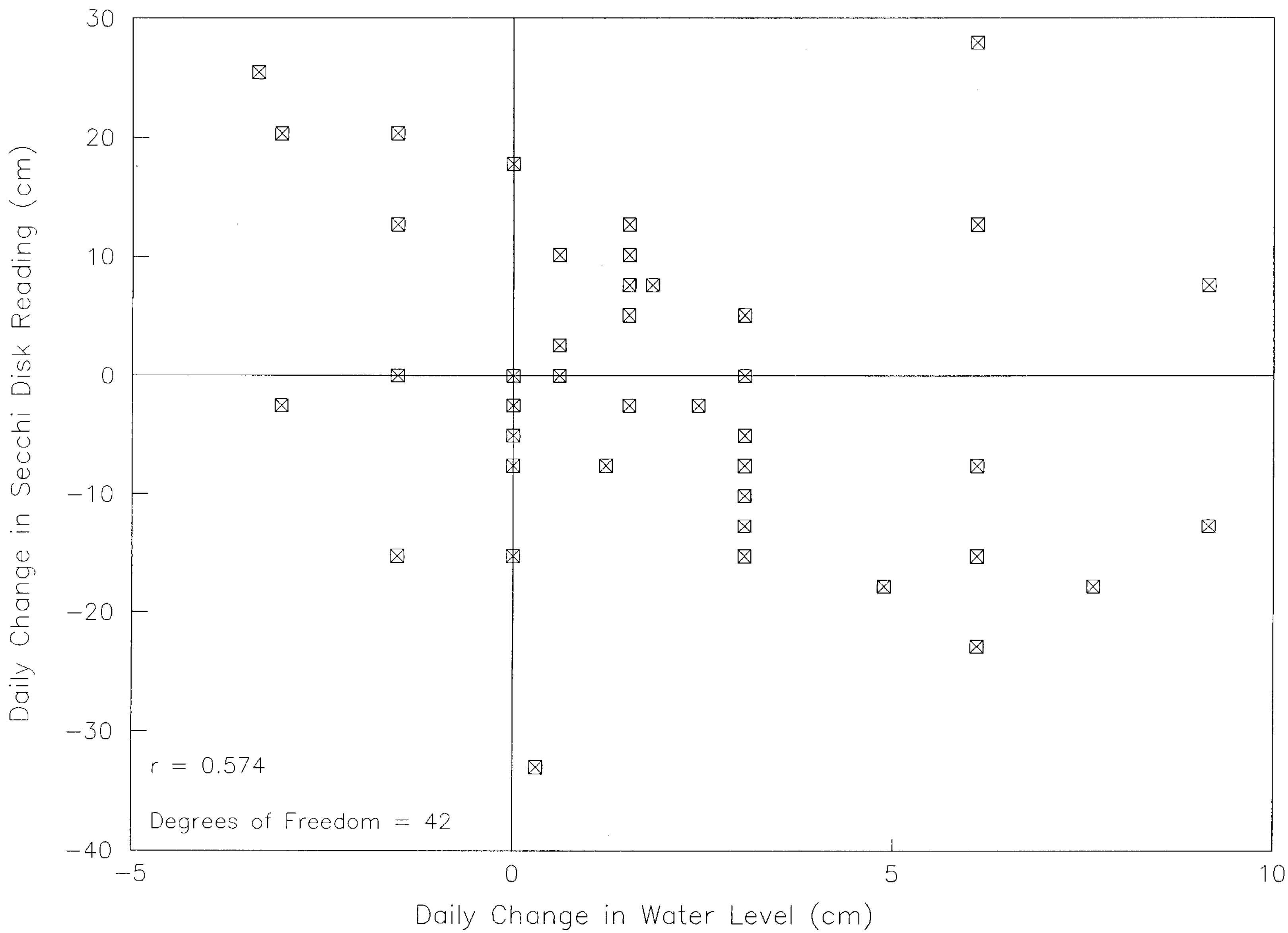


Figure 10. Daily change in turbidity as a function of change in water level in the Kenai River (km 31), 1992.

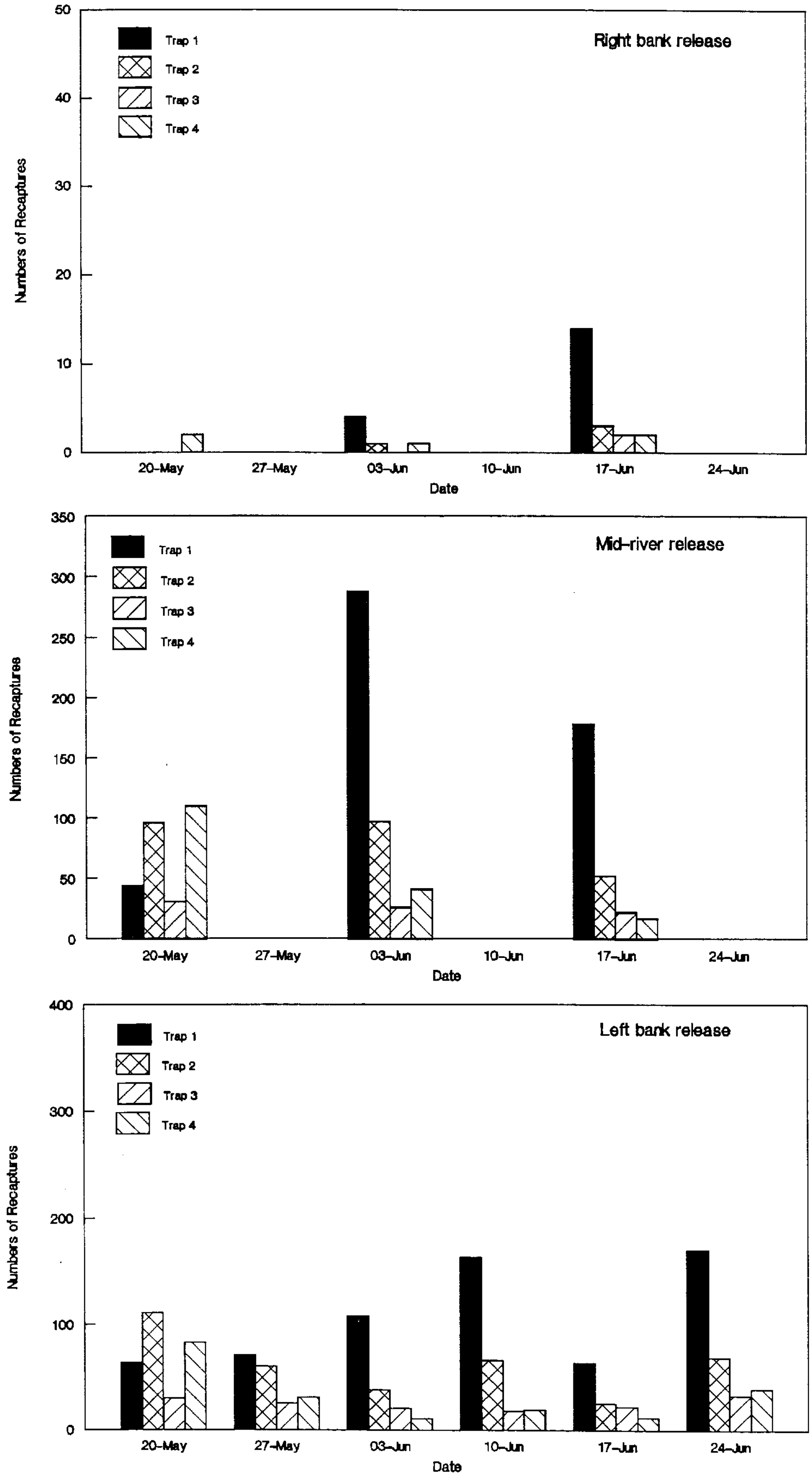


Figure 11. Number of inanimate objects captured in inclined plane traps from three release locations, Kenai River, 1992.

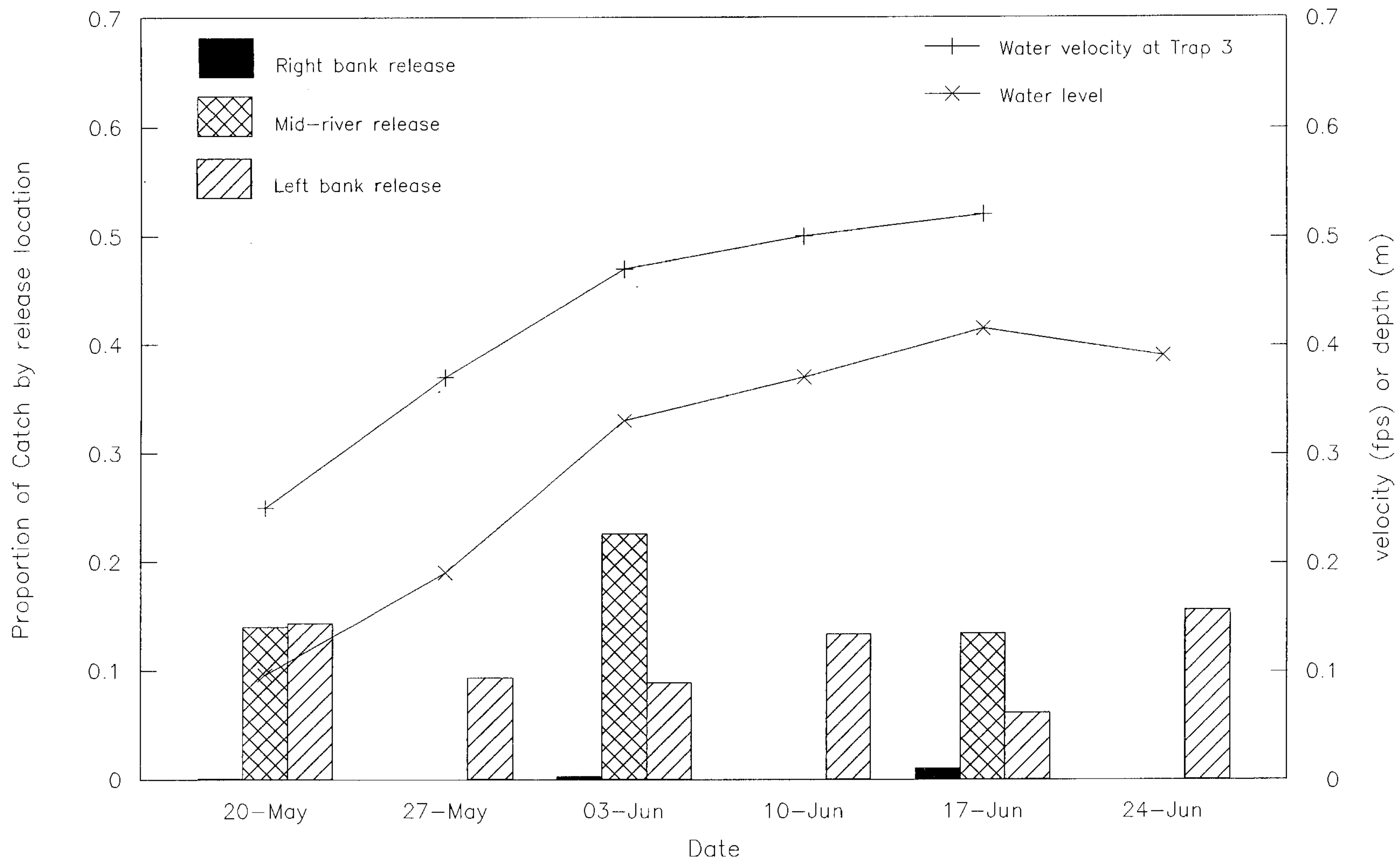


Figure 12. Total captures of inanimate objects released at three locations, and their relationship to water level and velocity, Kenai River, 1992.

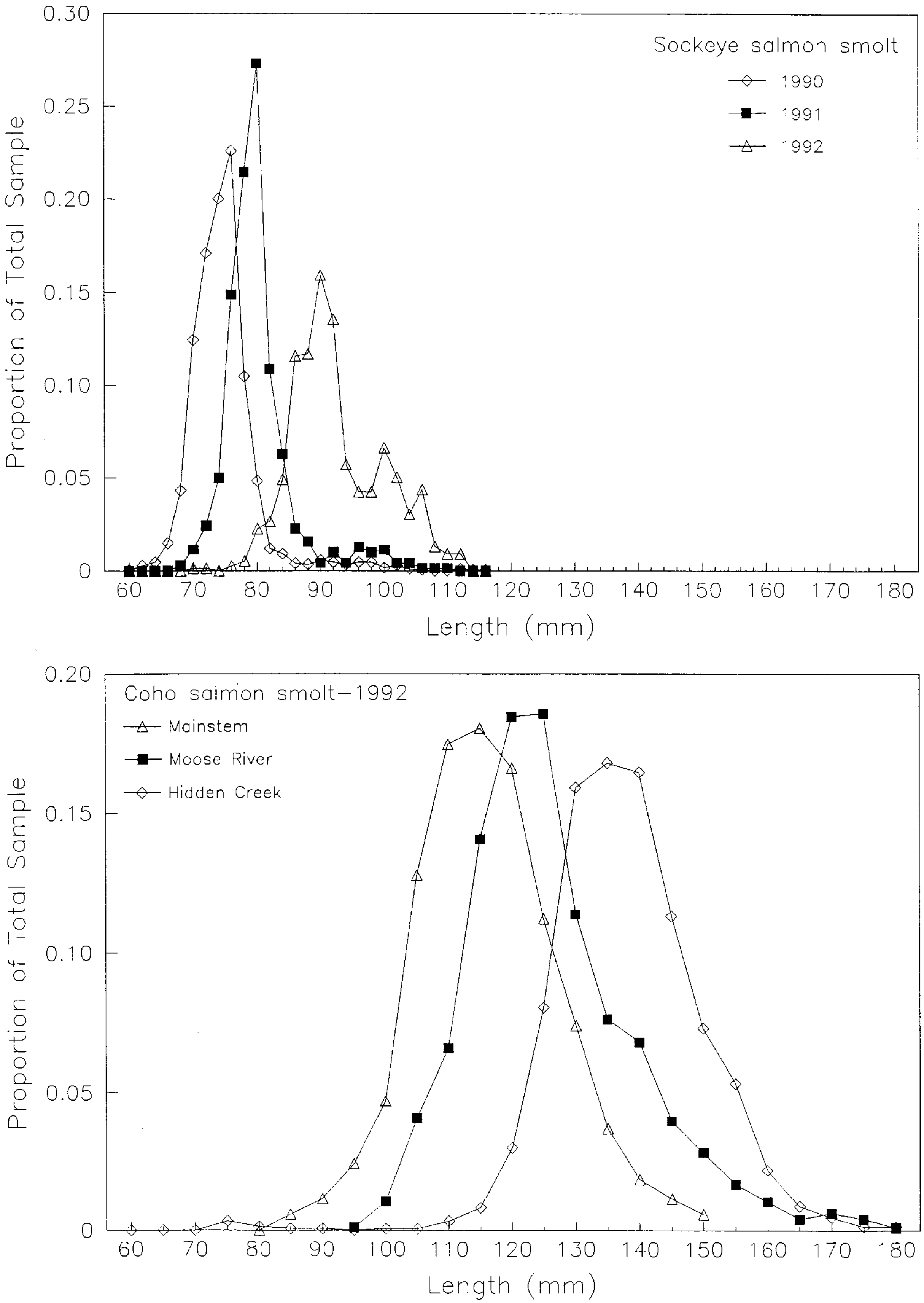


Figure 13. Length frequency distribution of age-2. sockeye salmon smolt, 1990-1992 (top), and all ages of coho salmon smolt, 1992 (bottom), captured in the Kenai River.

The Alaska Department of Fish and Game conducts all programs and activities free from discrimination on the basis of sex, color, race, religion, national origin, age, marital status, pregnancy, parenthood or disability. For information on alternative formats available for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD) 1=800-478-3648 or (fax) 907-586-6596. Any person who believes s/he has been discriminated against should write to: ADF&G, PO Box 25526, Juneau, AK 99802-5526; or O.E.O., U.S. Department of the Interior, Washington, DC 20240.